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Biological Services Program

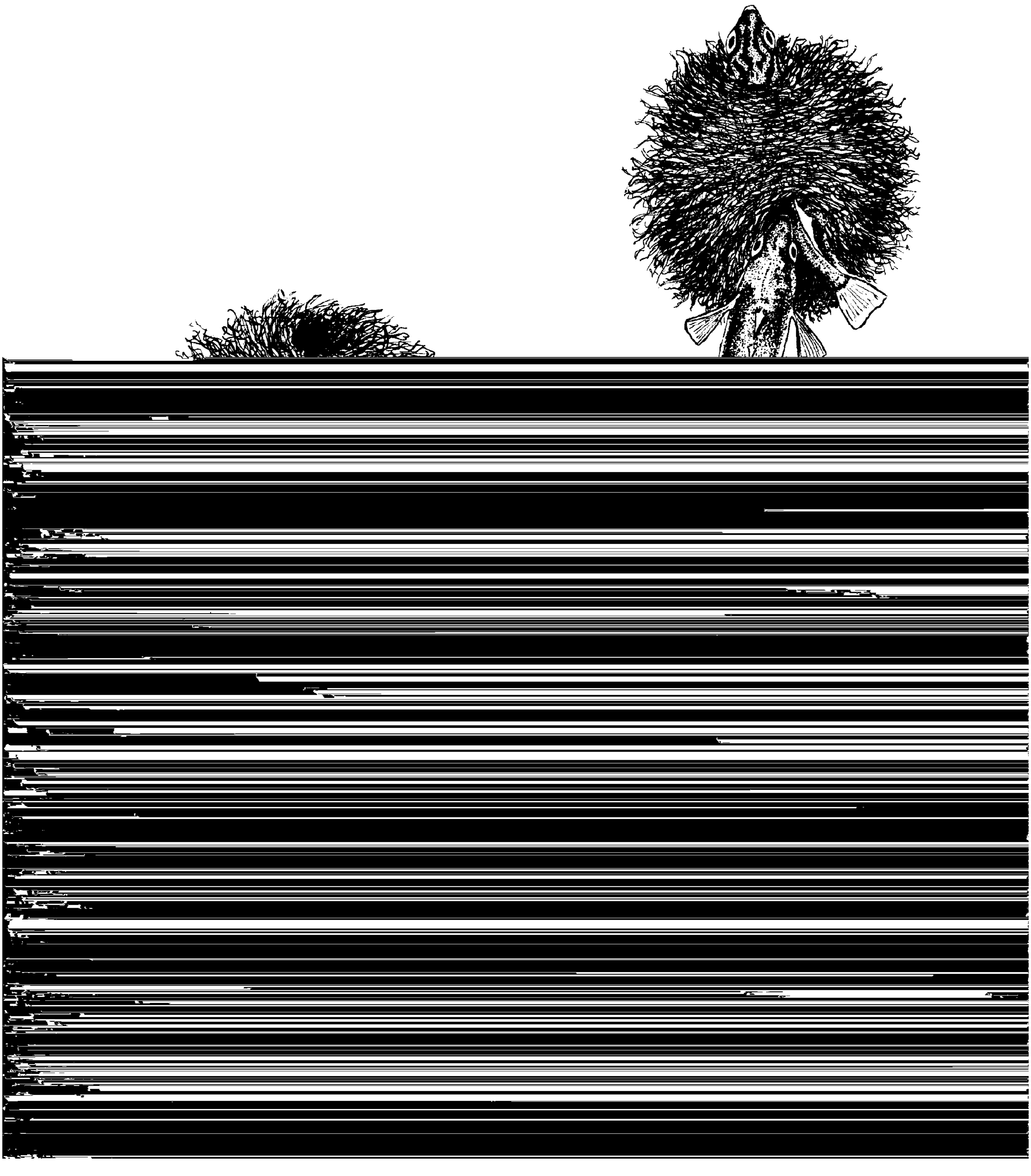
DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME

II

ANGUILLIDAE THROUGH SYNGNATHIDAE



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DEVELOPMENT OF FISHES OF THE MID-ATLANTIC BIGHT

AN ATLAS OF EGG, LARVAL AND JUVENILE STAGES

VOLUME II

ANGUILLIDAE THROUGH SYNGNATHIDAE

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Power Plant Project
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FOREWORD

The demand for electric energy often creates conflicts with the desire to preserve and protect the Nation's fish and wildlife resources. This is particularly true when the use of water for power plants is considered. Power plants require large volumes of water from rivers, lakes, reservoirs, and estuaries. Withdrawal of water for cooling purposes causes the loss of fish eggs, larvae, and juveniles through impingement or entrainment. The discharge of water causes thermal and chemical pollution, and can cause alteration of stream flow patterns and the disruption of the thermal and dissolved oxygen stratification in those water bodies.

The biological consequences of water use by power plants depend upon the species of organisms involved, the mechanical and physiological stresses on the organisms, and the ecological role of the organisms. To assess the impacts of power plants and other habitat modifications on fish populations, it is necessary to identify fish eggs, larvae, and juveniles of different species. However, up to now, descriptions of the developmental stages of fishes have been scattered throughout a large number of sources.

The *Development of Fishes of the Mid-Atlantic Bight* is a reference which compiles descriptions of the egg, larval, and juvenile stages of over 300 fish species, and includes dichotomous keys useful for identifying species. Descriptions of spawning migrations and life habits of adult fishes, their geographic range and distribution, and movements of fish at all life stages are also included.

With this kind of baseline taxonomic information, biologists will be able to assess the management implications of power plant siting and other habitat modifications on aquatic populations and provide information to decision makers. We believe these books are a major step in providing the type of information necessary to incorporate environmental considerations into resource development decisions.

Lynn A. Greenwalt

Director, U.S. Fish and Wildlife Service

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues which impact fish and wildlife resources and their supporting ecosystems. The mission of the Program is as follows:

1. To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
2. To gather, analyze, and present information that will aid decision makers in the identification and resolution of problems associated with major land and water use changes.
3. To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Services Program is intended for use in the planning and decision making process to prevent or minimize the impact of development on fish and wildlife. Biological Services research activities and technical assistance services are based on an analysis of the issues, the decision makers involved and their information needs, and an evaluation of the state of the art to identify information gaps and determine priorities. This is a strategy to assure that the products produced and disseminated will be timely and useful.

Biological Services projects have been initiated in the following areas:

- Coal extraction and conversion
- Power plants
- Geothermal, mineral, and oil shale development
- Water resource analysis, including stream alterations and western water allocation
- Coastal ecosystems and Outer Continental Shelf development

CONTENTS

GENERAL INTRODUCTION

As noted by Mansueti and Hardy (1967) in the first edition of Volume I of this series, the early developmental stages of most fishes are either poorly known or completely unknown. Despite the fundamental importance of this knowledge to many aspects of fishery biology and ichthyology, this situation still persists.

OBJECTIVES

The primary purpose of this series is to synthesize the world literature on fishes occurring in the Mid-Atlantic Bight of the United States. The successful accomplishment of this goal serves a number of useful functions, among which are greater ease in identifying young fishes and fish eggs, the systematization of information gaps, and the stimulation of studies in areas where such gaps have been clearly demonstrated. Although some original data have been included in this series, time constraints have kept this to a minimum, primary efforts having been directed toward a comprehensive review of existing literature.

FORMAT

The geographical area considered extends from the northern boundary of New Jersey to the southern boundary of Virginia from tidal freshwater out to the 100 fathom contour (see fig. 1).

Data have been presented on 321 species. Mansueti and Hardy (1967) arranged the species in Volume I in the sequence used by the American Fisheries Society (1960). Although disagreements exist with this arrangement as a phylogenetic sequence it is used here to order the species and families in this series so that the revised Volume I will remain intact. In some cases recent systematic revisions have demanded realignment at familial levels or the updating of generic and specific names.

The series is presented in six volumes as follows: Volume I, Acipenseridae through Ictaluridae, 50 species; Volume II, Anguillidae through Syngnathidae, 48 species; Volume III, Aphredoderidae through Rachycentridae, 52 species; Volume IV, Carangidae through Ephippidae, 52 species; Volume V, Chaetodontidae through Ophidiidae, 52 species; and Volume VI, Stromateidae through Ogcocephalidae, 67 species.

Species accounts are arranged alphabetically within family groupings. Each species account is divided into the following major divisions:

ADULTS—meristics, morphometrics and general description.

DISTRIBUTION AND ECOLOGY—range, habitat and movements of adults, larvae, and juveniles.

SPAWNING—description of season, location, conditions of spawning, and fecundity.

EGGS—description of ripe ovarian, unfertilized or fertilized eggs.

EGG DEVELOPMENT—developmental sequences, physical limiting factors and incubation times.

YOLK-SAC LARVAE—size range, morphology, development and pigmentation.

LARVAE—size range, morphology, development and pigmentation.

PREJUVENILES (not recognized in all volumes)—size range, morphology, development and pigmentation.

JUVENILES—size range, morphology, development and pigmentation.

GROWTH (not given in all volumes)—average and/or representative growth rates, especially preadult growth.

AGE AND SIZE AT MATURITY—average age and size at maturity plus variation if these data are available.

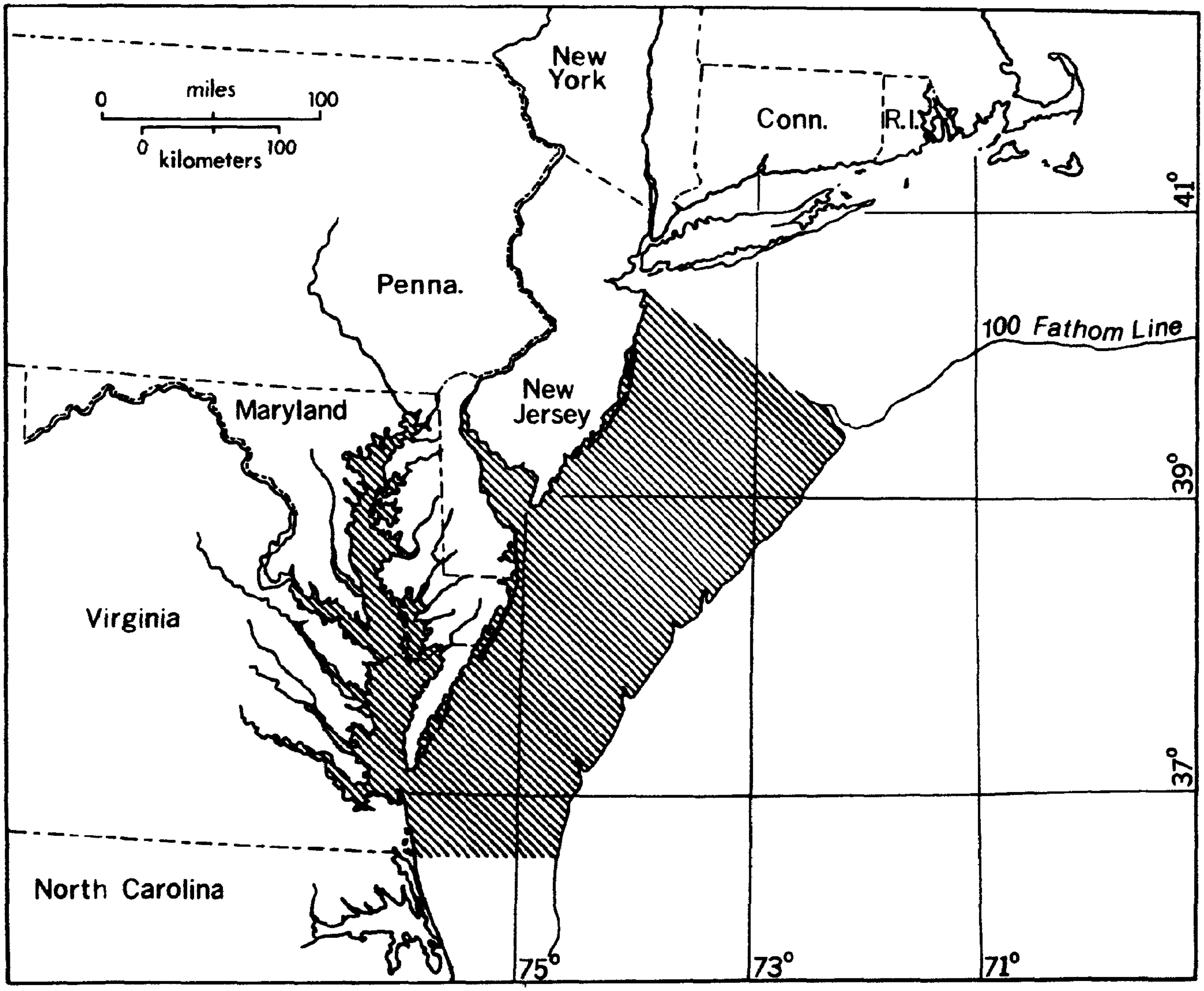


Fig. 1. Map of the Chesapeake Bay and adjacent Mid-Atlantic Bight. Hatching indicates the area considered in this series.

Literature cited—abbreviated citations to literature consulted for that account. Complete citations in Bibliography.

Superscript numbers in each species account refer to the abbreviated citations given at the end of each account. Complete citations may be found in the bibliography at the end of each volume. In prefaces, introductions, family accounts and figure legends, citations are given by author and date, rather than superscript. Throughout, parenthetical initials follow original unpublished information provided by the person whose initials are given (see preface for full name and address). Each volume has its own bibliography and index. No cumulative bibliography or index has been attempted.

Illustrations are of mixed quality and utility. For the most part they are simply reprinted from the literature. In some cases, however, previously published figures have been redrawn, and a number of original illustrations are included. Figure legends cite the artist or delineator. Redrawings are usually of figures which are unique in that they provide the only illustrations of particular features or stages and will not reproduce well or are confusing or inaccurate in detail. Attempts have been made to exclude drawings of misidentified specimens; however, error in judgement is possible. Where available, multiple illustrations of the same stage are included if they show geographic variation or if the authors were unable to determine which illustration provided the most accurate representation. In addition, a number of drawings which have been published in rare or generally unavailable sources have been included primarily for their historic value.

TERMINOLOGY

For the most part, terminology and methods of measuring and counting are those of Hubbs and Lagler (1958); however, these terms are specifically for adult forms and must be modified or replaced by different ones for early developmental stages.

For illustrations of typical developmental stages and larval anatomy see fig. 2.

Definitions and terms for developmental stages vary considerably depending on the investigator and the species worked on. The following terminology has been standardized:

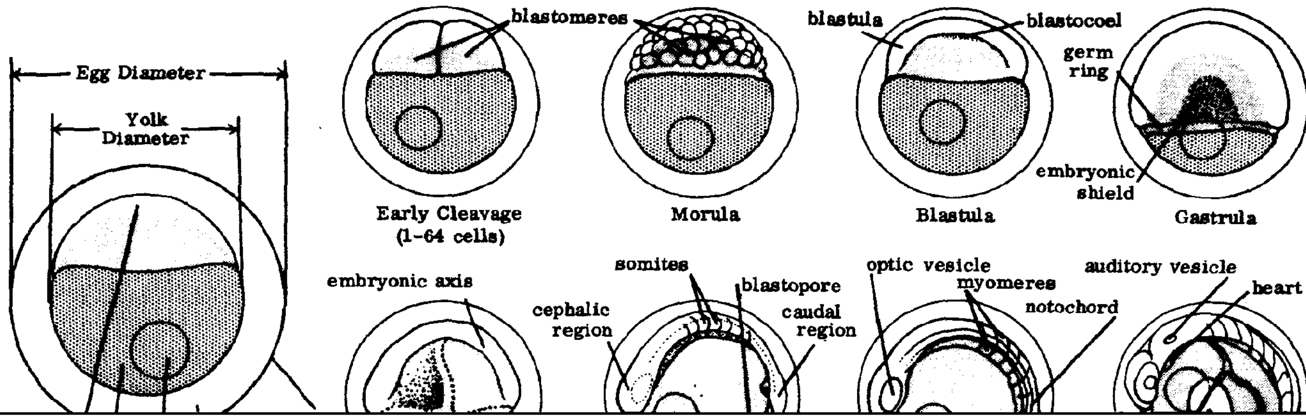
YOLK-SAC LARVA—stage between hatching and absorption of yolk;

LARVA—stage between absorption of yolk and acquisition of minimum adult fin ray complement;

PREJUVENILE—stage between acquisition of minimum adult fin ray complement and assumption of adult body form; used only where strikingly different from juvenile (cf. Hubbs, 1958; *Tholichthys* stage of butterflyfishes, querimana stage of mullets, etc.);

JUVENILE—stage between acquisition of minimum adult fin ray complement and sexual maturity or between prejuvenile stage and adult;

ADULT—sexually mature.


Egg Diameter
Yolk Diameter
blastomeres
Early Cleavage (1-64 cells)
Morula
blastula
blastocoel
Blastula
germ ring
embryonic shield
Gastrula
embryonic axis
somites
blastopore
cephalic region
caudal region
optic vesicle
myomeres
notochord
auditory vesicle
heart

GLOSSARY

A. Abbreviation for anal fin.

abbreviate heterocercal. Tail in which the vertebral axis is prominently flexed upward, only partly invading upper lobe of caudal fin; fin fairly symmetrical externally.

adherent. Attached or joined together, at least at one point.

adhesive egg. An egg which adheres on contact to substrate material or other eggs; adhesiveness of entire egg capsule may or may not persist after attachment.

adipose fin. A fleshy rayless median dorsal structure, located behind the true dorsal fin.

adnate. Congenitally united; conjoined.

adult. Sexually mature as indicated by production of gametes.

anadromous. Fishes which ascend rivers from the sea to spawn.

anal. Pertaining to the anus or vent.

anal fin. Unpaired median fin immediately behind anus or vent.

anal fin origin. Anteriormost point at which the anal fin attaches to the body.

anlage. Rudimentary form of an anatomical structure; primordium.

anus. External orifice of the intestine; vent.

auditory vesicle. Sensory anlage from which the ear develops; clearly visible during early development.

axillary process. Enlarged, accessory scale attached to the upper or anterior base of pectoral or pelvic fins.

BL. Abbreviation for body length.

barbel. Tactile process arising from the head of various fishes.

blastocoel. Cavity of the blastula; segmentation cavity.

blastoderm. *Sensu strictu,* early embryonic tissue composed of blastomeres; more generally, embryonic tissue prior to formation of embryonic axis.

blastodisc. Embryo-forming area of egg prior to cleavage.

blastomeres. Individual cells formed during cleavage.

blastopore. Opening formed by and bordered by the germ ring as it extends over the yolk.

blastula. Stage in embryonic development which represents the final product of cleavage stages, characterized by formation of the blastocoel.

body length. A specialized method of measuring, generally applied only to billfishes, and defined by Rivas (1956a) as the distance from the tip of the mandible (with jaws closed) to the middle point on the posterior margin of the middle caudal rays.

branched ray. Soft ray with two or more branches distally.

branchial arches. Bony or cartilaginous structures, supporting the gills, filaments and rakers.

branchiostegals. Struts of bone inserting on the hyoid arch and supporting, in a fanwise fashion, the branchiostegal membrane; branchiostegal rays.

buoyant egg. An egg which floats free within the water column; pelagic.

C. Abbreviation for caudal fin.

caeca. Finger-like outpouchings at boundary of stomach and intestine.

catadromous. Fishes which go to sea from rivers to spawn.

caudal fin. Tail fin.

caudal peduncle. Area lying between posterior end of anal fin base and base of caudal fin.

cheek. Lateral surface of head between eye and opercle, usually excluding preopercle.

chorion. Outer covering of egg; egg capsule.

choroid fissure. Line of juncture of invaginating borders of optic cup; apparent in young fish as a trough-like area below lens.

chromatophores. Pigment-bearing cells; frequently capable of expansions and contractions which change their size, shape, and color.

cirrus. Generally small, dermal, flap-like or tentacle-like process on the head or body.

cleavage stages. Initial stages in embryonic development where divisions of blastomeres are clearly marked; usually include 1st through 6th cleavages (2–64 cells).

cleithrum. Prominent bone of pectoral girdle, clearly visible in many fish larvae.

ctenoid scale. Scales with comb-like margin; bearing cteni.

cycloid scale. Scales with evenly curved free border, without cteni.

D. Abbreviation for dorsal fin.

demersal egg. An egg which remains on the bottom, either free or attached to substrate.

dorsal fins. Median, longitudinal, vertical fins located on the back.

dorsal fin origin. Point where first dorsal ray or spine attaches to body.

heterocercal. Tail in which the vertebral axis is flexed upward and extends nearly to tip of upper lobe of *melanophores.* Black chromatophores.

mental. Pertaining to the chin.

meroblastic. Type of cleavage in which only the blastodisc undergoes division.

micropyle. Opening in egg capsule through which spermatozoa enter.

morula. Stage in development of egg in which blastomeres form a mulberry-like cluster.

myomeres. Serial muscle bundles of the body.

myoseptum. Connective tissue partitions separating myomeres.

nape. Area immediately posterior to occipital region.

nasal. Pertaining to region of the nostrils, or to the specific bone in that region.

NL. Abbreviation of notochord length.

notochord. Longitudinal supporting axis of body which

perivitelline space. Fluid-filled space between egg proper and egg capsule.

pharyngeal teeth. Teeth on the pharyngeal bones of the branchial skeleton.

postanal myomeres. The number of myomeres between posterior margin of anus and the most posterior myoseptums.

preanal length. Method of measuring often not stated, assumed to be about equivalent to snout to vent length in larvae.

preanal myomeres. The number of myomeres between the anteriormost myoseptum and the posterior margin of anus.

predorsal scales. Scales along dorsal ridge from occiput to origin of dorsal fin.

prejuvenile. Developmental stage immediately following acquisition of minimum fin ray complement of ments; not applicable to larvae prior to notochord flexion. (In juveniles and adults measured from most anterior point of snout or upper lip.)

stomodeum. Primitive invagination of the ectoderm which eventually gives rise to the mouth.

tail-bud stage. Stage of embryonic development characterized by a prominent caudal bulge and marked development of cephalic region.

ventral fins. Paired fins articulating with the pelvic girdle; pelvic fins.

vitelline vessels. Arteries and veins of yolk region.

water-hardening. Expansion and toughening of egg capsule due to absorption of water into the perivitelline space.

width of perivitelline space. Distance between yolk and egg capsule expressed either as direct measurement

VOLUME II DEDICATION

This volume is dedicated to Dr. L. Eugene Cronin, former Director of Chesapeake Biological Laboratory, Solomons, Maryland, in recognition of his total and honest devotion to the Chesapeake Bay.

INTRODUCTION TO VOLUME II

This volume contains accounts of the life histories and development of forty-eight species of teleostean fishes occurring in the Mid-Atlantic Bight (Anguillidae through Syngnathidae). It is primarily a compilation of previously published information but also includes some unpublished data and a number of original illustrations. These include the following:

Anguilla rostrata adult	Daniel M. Carver
Conger oceanicus adult	Daniel M. Carver
Pisodonophis cruentifer leptocephalus	Alice J. Lippson
Ablennes hians juvenile	Nancy S. Smith
Strongylura marina eggs, larvae	Peni G. Long
Hemiramphus brasiliensis juvenile	Jerry D. Hardy, Jr.
Hyporamphus unifasciatus eggs, larvae	Elizabeth R. Peters Jerry D. Hardy, Jr. Nancy S. Smith William L. Dovel
Cyprinodon variegatus larvae	Linda L. Hudson
Fundulus confluentus eggs, larvae	Elizabeth R. Peters Linda L. Hudson
Fundulus diaphanus larvae	Linda L. Hudson
Fundulus heteroclitus larvae	Linda L. Hudson
Fundulus luciae eggs, larvae	Elizabeth R. Peters
Fundulus majalis larvae	Linda L. Hudson
Lucania parva larvae	Linda L. Hudson Nancy S. Smith
Enchelyopus cimbrius juvenile	Nancy S. Smith
Microgadus tomcod eggs, larvae	Jerry D. Hardy, Jr.
Phycis chesteri juvenile	Elizabeth R. Peters
Urophycis tenuis juvenile	Virginia Inst. Mar. Sci.
Apeltes quadracus larvae	William L. Dovel
Hippocampus erectus eggs, larvae	Linda L. Hudson
Syngnathus floridae larvae	Alice J. Lippson

Syngnathus fuscus larvae	Alice J. Lippson

Original text contributions are indicated by initials as follows:

JEB James E. Böhlke, Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania.
BBC Bruce B. Collette, National Marine Fisheries Service, U.S. National Museum, Washington, D.C.
GED George E. Drewry, Chesapeake Biological Laboratory, Solomons, Maryland.
WLD William L. Dovel, Boyce Thompson Institute, Yonkers, New York.
MPF Michael P. Fahay, National Marine Fisheries Service, Northeast Fisheries Center, Sandy Hook, New Jersey.
NRF Neal R. Foster, U.S. Fish and Wildlife Service, Ann Arbor, Michigan.
RAF Ronald A. Fritzsche, University of Mississippi, University, Mississippi.
JDH Jerry D. Hardy, Jr., Chesapeake Biological Laboratory, Solomons, Maryland.
AJL Alice J. Lippson, Martin-Marietta Corporation, Baltimore, Maryland.
PGL Peni G. Lang, formerly Chesapeake Biological Laboratory, Solomons, Maryland.
FDM F. Douglas Martin, Chesapeake Biological Laboratory, Solomons, Maryland.
JAM John A. Musick, Virginia Institute of Marine Science, Gloucester Point, Virginia.
RRM Robert R. Marak, National Marine Fisheries Service, Narragansett, Rhode Island.
DGS David G. Smith, Marine Biomedical Institute, Galveston, Texas.
NSS Nancy S. Smith, St. Petersburg, Florida.
RLW Robert L. Wisner, Scripps Institute of Oceanography, La Jolla, California.

I wish to thank the following individuals for reviewing the various manuscripts: Kenneth W. Able, Rutgers University, New Brunswick, New Jersey, for reviewing *Fundulus heteroclitus;* Bruce B. Collette, National Marine Fisheries Service, U.S. National Museum, Washington, D.C., for reviewing Belonidae and Hemiramphidae; Charles E. Dawson, Gulf Coast Research Laboratory, Ocean Springs, Mississippi, for reviewing Syngnathidae; Michael P. Fahay, National Marine Fisheries Service, Northeast Fisheries Center, Sandy Hook, New Jersey, for reviewing Anguillidae, Muraenidae, Congridae, and Opichthidae; Neal R. Foster, U.S. Fish and Wildlife Service, Ann Arbor, Michigan, for reviewing Cyprinodontidae exclusive of *Fundulus heteroclitus;* Ronald A. Fritzsche, University of Mississippi, for reviewing Exocoetidae, Fistulariidae, and Macrorhamphosidae; William H. Krueger, University of Rhode Island, Kingston, Rhode Island, for reviewing Gasterosteidae; Robert R. Marak, National Marine Fisheries Service, Narragansett, Rhode Island, for reviewing Gadidae (in part); F. Douglas Martin, Chesapeake Biological Laboratory, Solomons, Maryland, for reviewing Poeciliidae and Aphredoderidae; John A. Musick, Virginia Institute of Marine Science, for reviewing Gadidae (in part) and Merlucciidae; and Robert L. Wisner, Scripps Institute of Oceanography, La Jolla, California, for reviewing Scomberesocidae.

Work on this volume, prior to 1975, was supported entirely by funds from the Chesapeake Biological Laboratory. I am extremely grateful to Dr. L. Eugene Cronin for making that support possible.

I am especially grateful to our artist, Elizabeth Ray Peters, for her outstanding work on this project. Her original drawings of fish eggs and larvae are among the best which I have seen. I thank, also, Joan Ellis, Tamiko Karr, and Donna Davis, students from St. Marys College, for the numerous delineations which

they did as volunteer interns. Celeste Rollins, also a St. Marys student, prepared the figures used in several of the family introductions.

This project would probably not have been possible without the assistance given us by Jack Marquardt, librarian, U.S. National Museum; Leonard Bikowski and Hazel Dawson, of the Library of the U.S. Department of Interior; and Caroline Essex, librarian, Chesapeake Biological Laboratory. I will long remember the patience of these people in dealing with our numerous and often urgent calls for help.

George Drewry, research coordinator, kept the complex machinery of the project running smoothly, and, in its final stages, checked and standardized the bibliographies of this and two other volumes of the series. Julia Clark maintained and organized the reprint library—a task which became especially difficult as the momentum of the project increased. Judy Wiley, Ruth Wilson, and Herbert Harris assisted with the editing of the final manuscript, and Hillary Handwerger made a final check on the bibliographies of all six volumes of the series. The entire manuscript was reviewed and edited by Douglas Martin.

Vina Issacs and Walter Boynton, both former summer students at Chesapeake Biological Laboratory, assisted with library research and editing during the early stages of the development of the project. Ellen K. Sickles reared eggs and larvae of various species of *Etheostoma* while working as a summer aide. Peni G. Lang likewise reared and illustrated young stages of *Strongylura marina.* Linda Hudson, a summer aide in 1974, reared the eggs and larvae of all of the regional cyprinodontid larvae and illustrated most of them. Daniel M. Carver, a more recent summer student, assisted with the literature search, and also prepared a number of illustrations used in this volume. William Dovel supplied preserved tomcod larvae for illustrations, while Tom Peck and Michael Tabery obtained living eggs of this species from the Hudson River.

The patience exhibited by Cynthia Simmonds and Eunice (Sam) Benson in typing and re-typing the numerous manuscripts in this and the other five volumes of the series is almost beyond comprehension. I will always remember and appreciate their help. At times it became necessary to call in additional typists. These included Marjorie Blackwell, Joyce Stinson, Diane Haft, Clovia Hutchins, and Steven Drewry. Without their excellent work we would have probably met even fewer deadlines than we actually managed to meet.

Eurath Hardy, August Selckmann, Jr., and Ronald Bishop spent hundreds of hours in the darkroom when the rest of us were simply too busy to do so. A high percentage of the figures presented in this volume are the results of their volunteer efforts.

Anguilla rostrata

freshwater eels
Anguillidae

FAMILY ANGUILLIDAE

The family Anguillidae, of which there is one genus and about 15 species, occurs in all seas except the eastern Pacific and South Atlantic. Members of the family range north almost to the Arctic Circle and south to New Zealand.

In freshwater eels the body is covered with minute, embedded, cycloid scales; the gill slits are arranged vertically, their upper corners opposite the pectoral fins; and the dorsal fin originates far behind the pectorals.

The American eel, *Anguilla rostrata*, is the only regional member of the group. It is diadromous, moving from fresh and brackish water into the ocean to spawn. Although this species has been assumed to spawn in the vicinity of the Sargasso Sea, the actual spawning area may be much further south. Fertilized eggs have not been identified. The largest ovarian eggs thus far described were 0.6 mm in diameter. In ovarian eggs the yolk appears to be granular.

Leptocephali of the American eel are characterized by 102 to 110 myomeres, a straight gut, and no pigment. In the present volume growth stages are designated as follows:

Leptocephalus, stage I.	Length increasing.
Leptocephalus, stage II.	Length decreasing.
Glass eel, stage I.	Length decreasing.
Glass eel, stage II.	Length increasing.

For a comparison of the leptocephali of this species to those of the other regional fishes, see the key in the introduction to the family Ophichthidae.

Anguilla rostrata (Lesueur), American eel

ADULTS

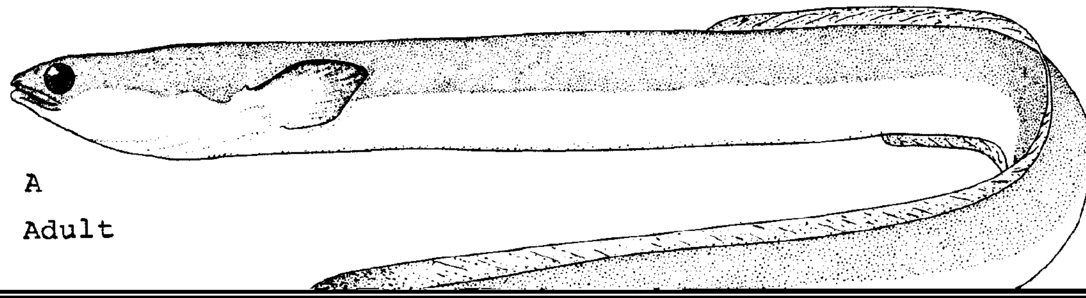
D. 183–276, mean 231.44;[53] A. 167–229,[26,32] mean 199.12;[53] C. 8–12 (4–6 + 4–6),[26] reported means 9.92, 10.09;[53] P. 14–20, mean 16.73;[29] vertebrae 103–111[22,26,32,80] (although Harden-Jones mentions an undetermined *Anguilla* leptocephalus from Mississippi with a vertebral count of 113);[19] average vertebrae 107.2;[38] precaudal vertebrae 41–46 (in Virginia waters 41–44); caudal vertebrae 61–68 (in Virginia waters 61–67);[53] branchiostegals 9–13,[26,32] mean ca. 11.0.[29,45]

Proportions as percent TL (in maximum-size but reproductively inactive males from Lake Sherman, Michigan): Head length 12.3–12.7, predorsal length 32.2–33.3, preanal length 41.8–42.0, pectoral length 7.5, interorbital width 2.5–2.6, horizontal diameter of eye 2.6–2.9, preorbital distance 2.3–2.7. Proportions as percent head length: interorbital width 20.3–20.6, horizontal diameter of eye 20.6–23.4, preorbital distance 18.8–21.4. Horizontal diameter of eye as percent of interorbital width (based on a number of specimens larger than minimum maturity size): in females 38.5 to ca. 89, in males ca. 80–100.[67]

Proportions as percent TL (based on silver eels migrating from Chesapeake Bay): Preanal length, males 39.4–43.8, females 36.6–45.2; predorsal length, males 29.1–35.6, females 30.8–36.7; head length, males 11.2–14.1, females 10.5–13.8. As percent of head length, gape length, males 16.7–26.9, females 19.7–32.1. As percent of gape length, horizontal diameter of eye, males 42–100, females 34.2–68.8.

Proportions as percent TL (based on 1 males and 11 females migrating in oceanic waters): Preanal length, males 42.3, females 40.8–44.8; predorsal length, males 33.8, females 32.8–35.6; head length, males 13.9, females 11.8–13.7. As percent of head length, gape length, males 21.7, females 21.2–27.9. As percent of gape length, horizontal diameter of eye, males 57.5, females 40.8–59.0.[71]

Body elongate, serpentine,[6,54] round anteriorly, compressed posteriorly[62] (but in beginning of stage much fatter than juveniles);[71] snout depressed, broad, blunt; mouth large, slightly oblique;[62] gape extended to posterior margin of eye;[43] lower jaw equal to or slightly longer than upper;[31] gill openings well separated, lateral and ventral; branchiostegals long; teeth in bands on jaws



A

Adult

and vomer.[14,43]

Scales small, cycloid,[43] placed at right angles to each other,[5] embedded,[33] and often difficult to see without magnification.[5] Lateral line well-developed,[33] accentu-

[redacted]

Medcof has noted that mature or maturing eels sometimes lie in inverted "U" 's over submerged or exposed stems of water plants; and sometimes form free floating or submerged balls which may be up to 2 meters in diameter. An eel ball 0.5 meters in diameter was

[redacted]

Migrate to the coast of North America in 1[9,44,54] or 2 years.[58]

From surface[35,52,54] to 1829 meters. Tåning obtained specimens 39.5–53.0 mm long from 914.4 to 1829 meters.[37] Other depth records are: Specimens 22 to 40 mm long at 25 meters;[38,44] metamorphosing leptocephali at 250 meters in Gulf of Mexico.[16] Leptocephali are apparently more easily collected at night[37] (presumably at surface, JDH).

Glass eels—coastal and offshore waters (JDH), also streams.[48] The transformation probably occurs when the young pass through the edge of the Gulf Stream.[25] Glass eels have been observed offshore at Georges and Browns Banks.[52] Specimens as small as 48 mm reported in Chesapeake and Narragansett bays;[12] a 47 mm specimen recorded from roots of water hyacinths in Florida.[15] Vladykov pointed out that total lengths of ascending "elvers" increase from southern to northern localities.[59]

From surface[52] to possibly 21.9 or 27.4 meters.[60]

Move shoreward, arriving in Delaware Bay and northeastern United States in March and in Nova Scotia in April.[68]

Elvers—coastal marine waters (usually in association with eel grass),[54] tidal flats,[12] tidal marshes, harbors, barrier beach ponds,[54] large coastal rivers,[6] creeks,[63] streams[55] (although seldom in cold streams), and warm, shallow lakes.[54] Apparently only females ascend to freshwater, males remain in estuarine waters.[9,13,57] Recorded from detritus covered bottom and in turbid water.[64] Specimens less than 150 mm long generally in shallow water near shore; larger individuals in deeper water of creek channels.[63]

Minimum recorded temperature, minus 0.8 C.[12]

Ascend streams in immense numbers (thus hundreds caught in a four-inch aquarium net).[10,56] Time, duration, and extent of upstream movement varies from year to year and in different localities (JDH). In Florida "elvers"

Swim near surface when ascending streams;[20] climb rocks to surmount obstacles;[18,31] also move through underground channels (including water pipes),[54] and leave streams during exceptionally heavy rains. May hide in gravel in streams,[55] and recorded hiding in moss in inverted position over water.[3]

Juveniles—tidal water (sometimes up to tide line)[17] in river channels; streams, particularly at obstructions in riffle areas, log jams, under overhanging banks, and in swampy areas; creeks; spring "boils;" underground streams in caves; marshes; ponds; lakes; and roadside ditches. Recorded over mud and sandy stone bottom; particularly abundant in heavily vegetated areas.[49,50,54]

Able to withstand abrupt salinity changes.[36]

Movements generally restricted while in headwaters of rivers, thus Gunning and Shoop noted a maximum movement of only 137.2 m in 10 to 13 months.[49] Vladykov, however, recorded a movement of 200 miles in 5 years and 11 months.[66] When experimentally displaced may return to rivers as far as 50 miles away.[61] In Canadian waters some immatures may migrate downstream with adults.[73]

Sometimes burrow in mud with only head protruding,[36] also hide in holes, or drape themselves over vegetation.[51] Hibernate in mud at depths of ca. 150–200 mm.[1,39,51,63,68] Hibernation sites apparently equipped with a ventilation hole.[54] May leave water at night, particularly during heavy rains, and crawl about on land;[3,31,51] and sometimes stranded on land by receding water.[42] Can survive up to 48 hours without water.[39,68]

SPAWNING

Location: Indefinite. Generally stated as between Bermuda (or southwest of Bermuda) and the West Indies,[9,12] or in the vicinity of the Sargasso Sea between latitudes 20° and 30° N and longitudes 60° and 75° W.[10,27] Small-

Fecundity: 413,000 to 2,561,000 based on counts from specimens migrating from Chesapeake Bay.[53] A count of 9,000,000 in a specimen from Long Island [40] may not be reliable (JDH). Estimates of 10,000,000 to 20,000,000 [19,31,54] are apparently not based on actual counts on this species.[74]

EGGS

Location: Assumed to be pelagic, floating in the upper to intermediate water layers,[52,53] but statement without direct supporting evidence (JDH).

Ovarian eggs: Mostly spherical (although smaller developing eggs cuboidal) with centrally located nucleus, and inclusions resembling yolk granules of *Brevoortia*.[53] Egg diameters of eels leaving Chesapeake Bay in November varied from 0.25–0.45 mm with an average of 0.356 mm.[71] Other ovarian egg size ranges in apparently migrating eels are: Newfoundland 0.109–0.214 mm, $\bar{x}=0.165$ mm; [72] south of Cape Cod 0.12–0.27 mm, $\bar{x}=0.17$ mm; [71] off northeastern United States, 0.17–0.37 mm, $\bar{x}=0.27$.[53] Growth of eggs was observed in four Canadian females between November and December. The diameters of these eggs have been reported as 0.33–0.45 mm (maximum size per female),[21] and 0.20–0.35.[30,45] There are indications that eels leave Chesapeake Bay later in the year and with the gonads more fully developed than in fishes from more northern localities (thus assuring that all eels will arrive in the spawning area at the same time and in the same state of reproductive development).[53] Maximum size of ripening eggs of *A. rostrata* obtained through hormone injection, 0.6 mm. Eggs larger than 0.5 mm are described as "loose" (presumably in the coelom).[30]

Presumably ripe, unfertilized eggs. Diameter 0.59–1.25 mm, average 1.06; transparent; slightly ellipsoidal; a number of relatively large, various-sized oil globules.[75]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

Undescribed except for comments by Eldred and Raney that recently hatched larvae are 7–9 mm long and that the hatchlings may be ca. 6 mm long.[16,28]

STAGE I, LEPTOCEPHALUS

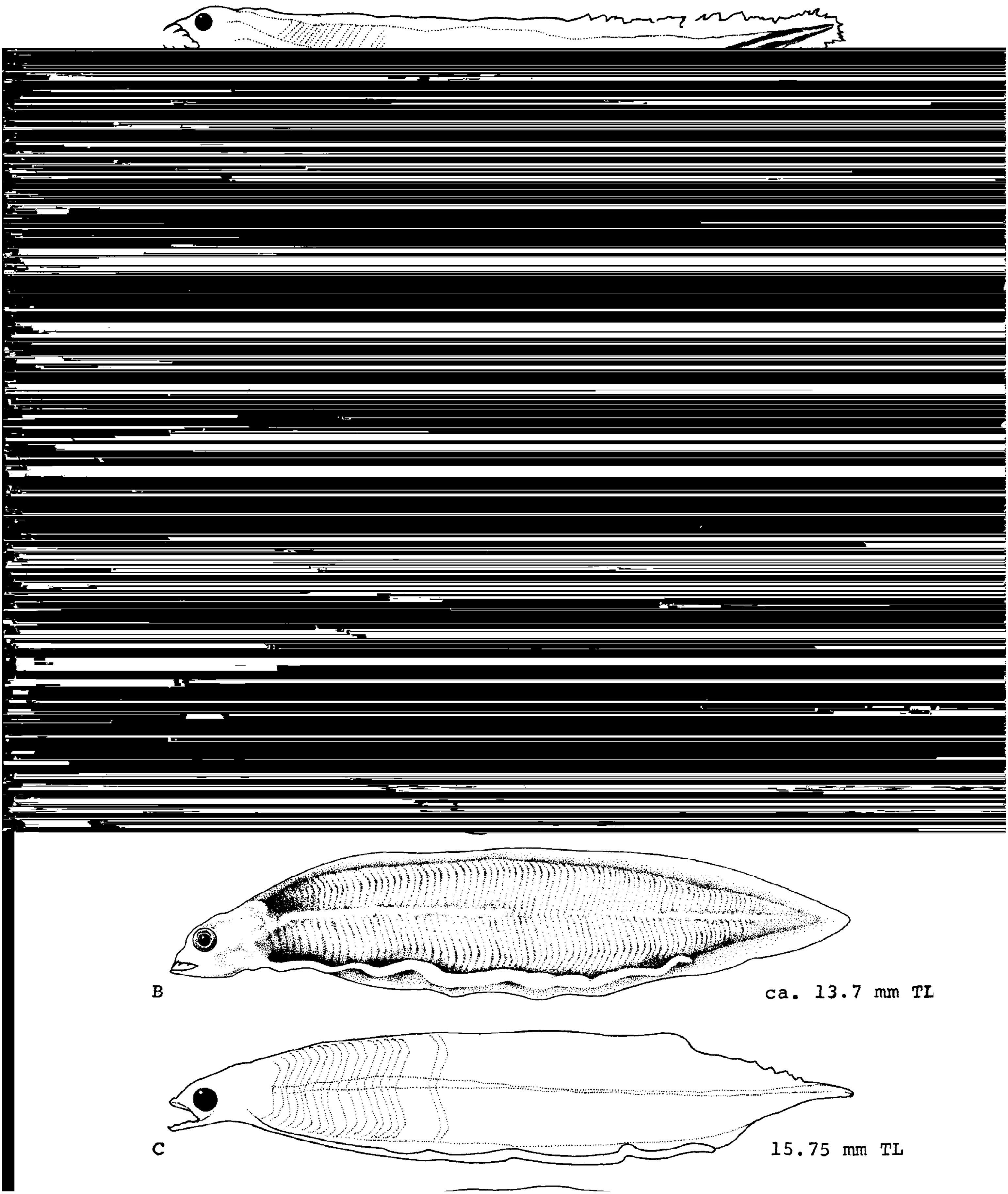
Size range described, 10.5–69.0 mm.[81]

Total myomeres, at 10.5 mm, 104–110; [24] at 18–58 mm, 102–110 (a specimen within this size range had 99 myomeres but was obviously malformed,[16,25] while another specimen of unspecified length had 101 myomeres [81]). Preanal myomeres, at 10.5 mm, 63; at 14.25–15.75 mm, 64; at ca. 22 mm, 68; [24] at 43.9–45.5 mm, 68–69; [16,19] at 47–49 mm, 65–68; [11] at 50 mm, 70; [27] at 51.5 mm, 71.[37] In specimens of unspecified stage or size, preanal myomeres 64–74.[81] Postanal myomeres, at 10.5 mm, 41–47; [24] at 43.9–45.5 mm, 36; [16,27] at 47–49 mm, 40; [11] at 50 mm, 34.[27] In specimens of unspecified stage or size, minimum postanal myomeres, 31.[81] Predorsal myomeres, at 43.9, 61; [27] at 45.5 mm, 62.[16] Myomeres between dorsal and anal origin, at 43.9, 8; [27] at 45.5 mm, 6; [16] at 47–49 mm, 8; [11] at 50 mm, 9. Branchiostegal rays undeveloped at 43.9 mm, 11 at 50 mm.[27]

Morphometric data is presented in Tables 1 and 2.

TABLE 1. Proportions as percent TL (derived from morphometric data presented by Eldred) [16,27]

Total length	*43.9 mm*	*45.5 mm*	*50.0 mm*
Preanal length	72.9%	73.4%	74.0%
Predorsal length	65.4	68.1	65.0
Postanal length	27.1	26.6	26.0
Head length	9.3	8.8	8.4
Depth at pectoral base	6.6	6.6	6.2
Maximum depth (level of renal-portal vein)	17.3	17.1	16.8
Depth at anus	16.0	16.4	14.4


B
ca. 13.7 mm TL
C
15.75 mm TL

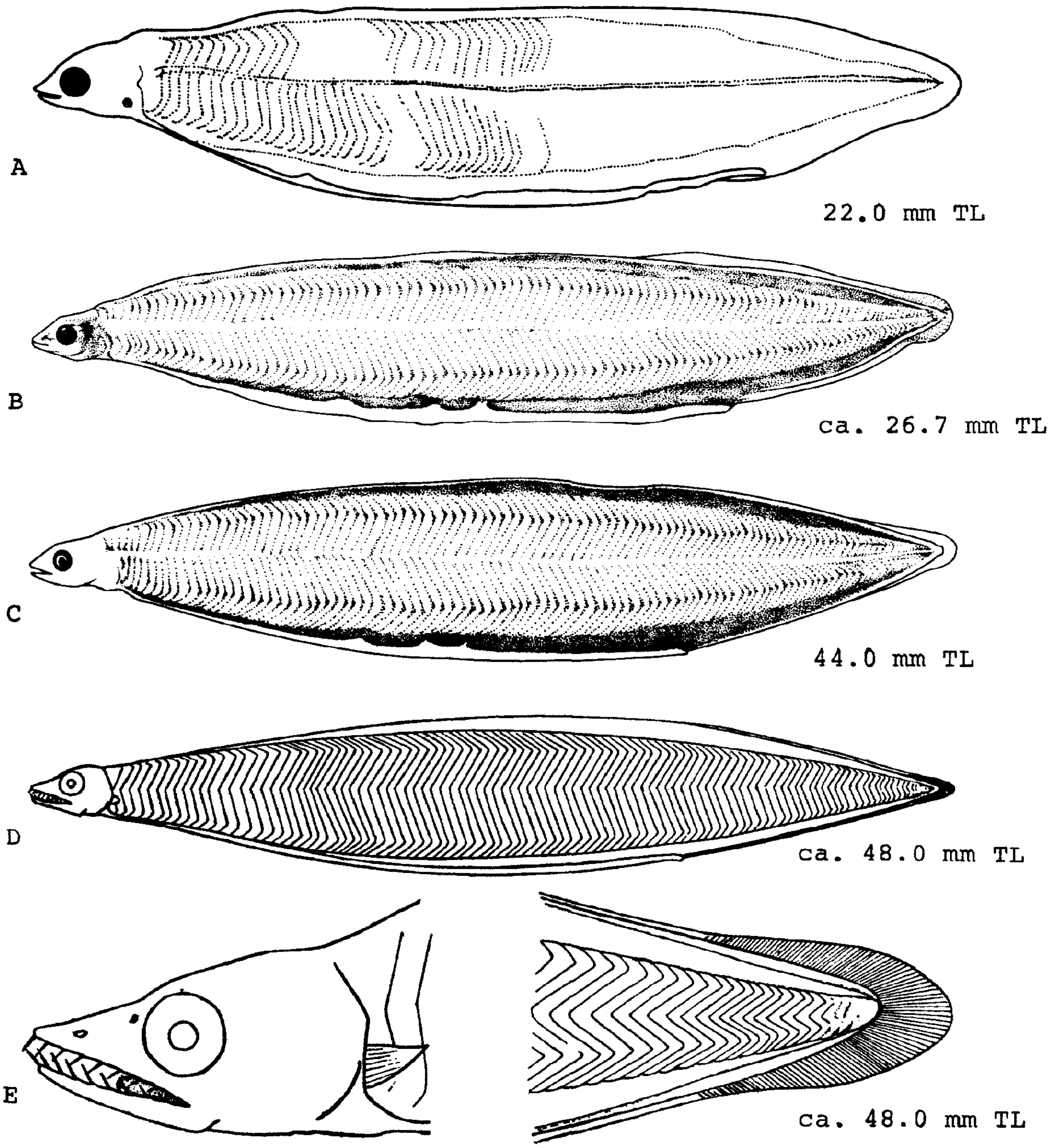
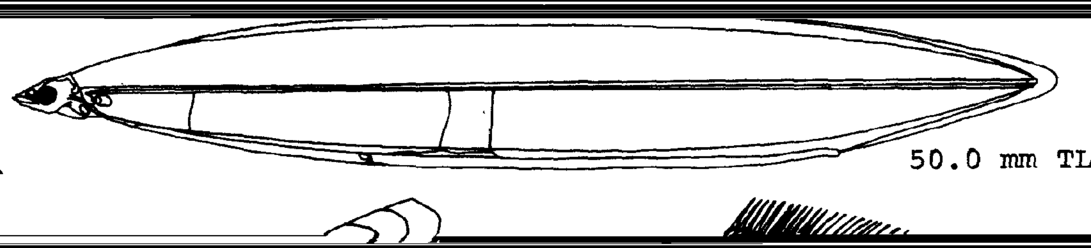


Fig. 6. *Anguilla rostrata*, American eel. A. Stage I leptocephalus, 22.0 mm TL. B. Stage I leptocephalus, ca. 26.7 mm TL. C. Stage I leptocephalus, 44.0 mm TL. D. Stage I leptocephalus, ca. 48.0 mm TL. E. Detail of [redacted]



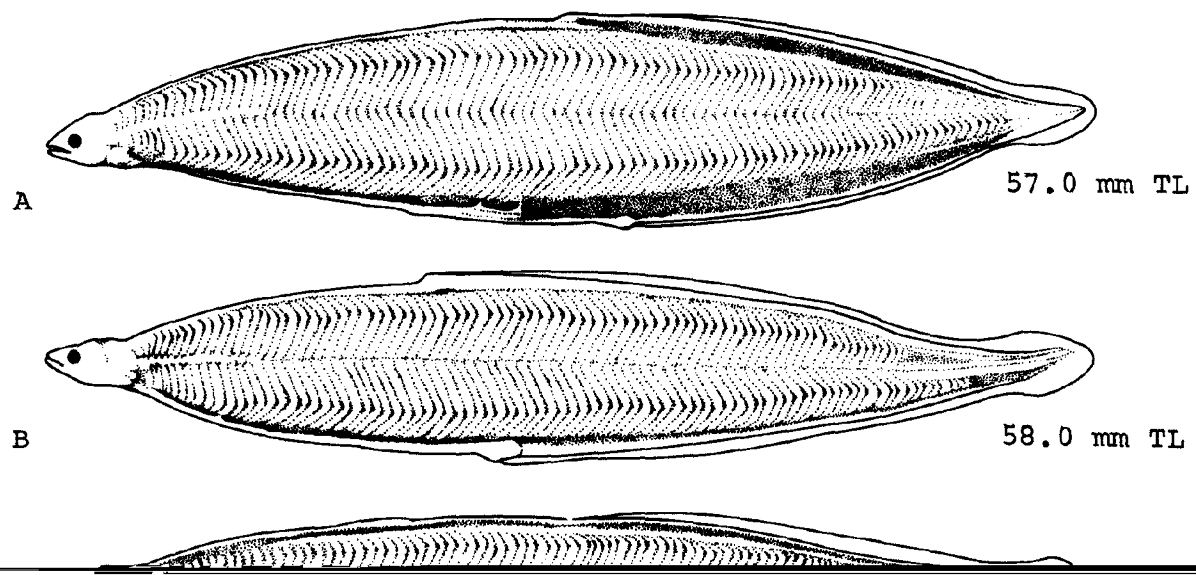
A
50.0 mm TL

margin of eye; nasal capsule small, oval; anterior nostril slightly tubular, at midpoint between tip of snout and anterior margin of eye; posterior nostril in front of eye.[27]

Dental formula: at 10.5 mm $\frac{1+3}{1+3}$; at 14.25 mm $\frac{1+4}{1+3}$; at 15.75 mm $\frac{1+5}{1+4}$; at ca. 22 mm $\frac{1+6}{1+5 \text{ or } 6}$;[24] at 43.9 mm $\frac{1+1+\mathrm{VIII}+6}{1+\mathrm{VII}+2}$;[27] at 45.5 mm $\frac{1+1+\mathrm{V}+7}{1+\mathrm{VIII}+2}$;[16] at 50 mm [redacted]

39.0 mm; postanal length, 18.0 mm; head length, 5.0 mm; snout length, 1.6 mm; horizontal diameter of eye, 0.9 mm; postcranial depth, 2.5 mm; depth at pectoral base, 3.6 mm; maximum depth (measured at level of renal-portal vein), 11.0 mm; depth at anus, 10.2 mm.[16]

At 71 to ca. 58 mm, body still essentially leptocephalous-like; at ca. 64–65 mm body depth greatly reduced. Head initially as in stage I leptocephalus; rounded by end of [redacted]


57.0 mm TL
A
58.0 mm TL
B

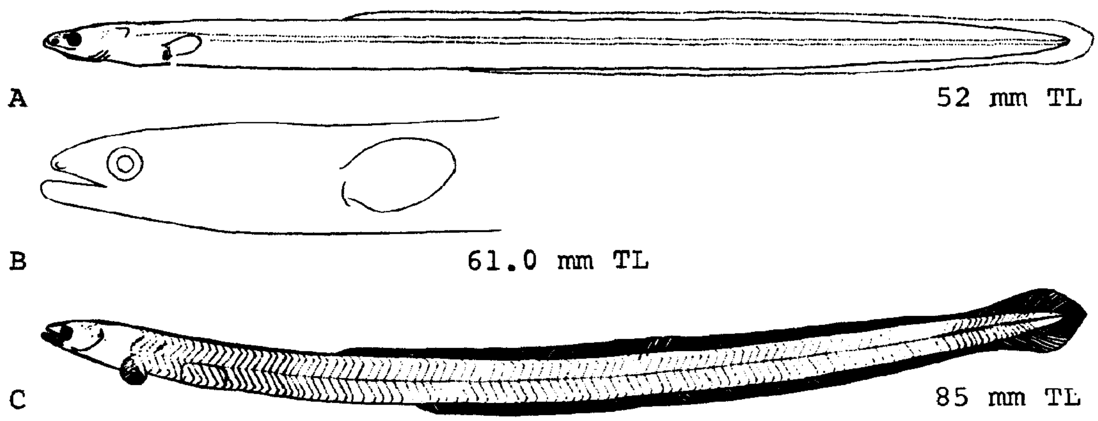

A
52 mm TL
B
61.0 mm TL
C
85 mm TL

TABLE 3. Proportions as percent TL (derived from morphometric data presented by Eldred) [27]

Total length	49.5 mm	50.0 mm	50.5 mm	51.5 mm	52.0 mm	52.2 mm
Preanal length	38.4%	38.0%	38.6%	36.9%	39.4%	29.5%
Predorsal length	26.1	30.0	31.3	29.7	30.8	31.8
Postanal length	61.6	62.0	61.4	63.1	60.6	60.5
Head length	11.1	11.0	8.1	11.7	11.5	11.5
Postcranial depth	1.3	3.6	4.4	3.7	3.9	3.8
Depth at pectoral base	4.1	4.0	6.1	3.9	3.9	3.8
Maximum depth (renal-portal vein)	4.1	4.0	3.4	3.3	4.2	4.8
Depth at anus	3.6	4.0	3.2	3.3	4.0	4.6

TABLE 4. Proportions as percent HL (derived from morphometric data presented by Eldred) [27]

Head length	5.5 mm	5.5 mm	4.1 mm	6.0 mm	6.0 mm	6.0 mm
Snout length	20.0%	18.2%	26.8%	17.7%	16.7%	19.2%
Horizontal diameter of eye	18.2	12.7	24.4	15.0	16.7	11.7

tip.[27] In a "large elver" (but apparently a glass eel with pigment just developing) cranial pigmentation similar to cerebral nerve cord spot described for European eel.[12]

ELVERS

Minimum size ca. 65 mm.[74]

Longest pectoral ray 6.0 times in HL in "young." [62]

Scales first evident at ca. 160 mm at mid-body and in caudal region. Scales not fully formed in these regions until ca. 200 mm. Anterior scales not evident until ca. 175 mm.[48]

Pigmentation: Fully pigmented at 65–90 mm,[74] brown and much like the adults as they ascend streams.[10,12]

JUVENILES

Maximum size, males ca. 280 mm or larger, females ca. 460 mm or larger (based on approximate minimum size at maturity).

Body elongate, snake-like.[6,54]

Proportions as percent TL (average values based on presumed immature females): Preanal length, 42.73–43.90; preanal length minus HL, 29.79–30.10; distance from dorsal origin to anus, 8.80–9.63; predorsal length minus HL, 20.23–21.01; head length 12.90–13.78.

Gape length as percent head length (average values, presumed immature females): 25.88–27.23.[41]

Proportions as percent TL (extreme values, presumed immature males): Head length, 12.0–12.6; predorsal distance, 30.3–33.0; preanal distance, 40.8–41.7; pectoral fin length, 4.2–5.0; interorbital width, 1.9–2.0; horizontal diameter of eye, 1.6–2.0; preorbital distance, 1.9–2.1.

Proportions as percent HL (extreme values, presumed immature males): Interorbital width, 14.7–16.7; horizontal diameter of eye, 12.5–16.7; preorbital distance, 15.6–17.3.

Horizontal diameter of eye as percent interorbital width (extreme values, presumed immature males), 81.3–100.0; in males of less than 299 mm (thus less than or near to minimum maturity size), 62.5–83.3; in females less than 499 mm (thus less than or near to minimum maturity size), 45.5–93.6.

Horizontal diameter of eye as percent interorbital distance (extreme values, presumed immature males), 72.2–106.7.[67]

Horizontal diameter of eye as percent of gape (presumed juveniles, sex unknown), 30.7–59.1, $\bar{x}$ 41.8.[53]

Depth as times in HL (presumed juveniles, sex unknown), 1.65–2.65.[62]

Pectoral fin rounded, not pointed.[67]

Pigmentation: "Half grown" eels, predominately yellow or green.[61] Otherwise brown, dark brown, or olive brown above; sides tinged with yellow or yellow-green; lower sides brown; venter white, dirty yellowish white, golden, or dirty yellow.[6,31,52,62]

AGE AND SIZE AT MATURITY

Age at maturity, variously estimated from 5 to possibly 18 years.[9,10,55,58]

Minimum length at maturity, males ca. 280 mm, females ca. 457 mm,[52] although one author states that females are "frequently" mature at lesser sizes.[54]

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Gymnothorax funebris

morays
Muraenidae

FAMILY MURAENIDAE

The muraenids, of which there are two subfamilies, 12 genera, and about 100 species, occur in tropical, subtropical, and, rarely, temperate waters (the regionally rare species, *Gymnothorax funebris,* has been recorded as far north as Canada). These secretive, nocturnal eels are almost exclusively restricted to reefs or rocky areas within the 46 meter isobath and are rarely if ever found in the open sea.

Morays may be recognized by the following characteristics: the anterior nostril is tubular and the posterior nostril is high on the head above or slightly in front of the eye; the gill openings are noticeably small and roundish; the jaws are usually equipped with long, depressible canine teeth; there are two branchial pores; the fourth branchial arch is strengthened and supported by pharyngeal jaws; there are lateral line pores on the head, but not on the body; the body is somewhat compressed; scaleless; pectoral fins are absent; and, in some genera such as *Uropterygius,* the dorsal and anal fins are vestigial. Many morays reach maximum lengths of 4 or 5 feet, but some species grow to extreme lengths of 10 feet.

The eggs of muraenids are generally not well known. *Muraena helena* produces extremely large, pelagic eggs (diameter 5.5 mm) in which the yolk is granular and there are no oil globules. In spite of several recent statements that morays may lack a leptocephalous stage, leptocephali of a number of species have been described. In these the intestine lacks "loops" and occupies 40 to 65% of the standard length; the tail is broadly rounded. Pigment is usually present. The pectoral buds may be very poorly developed and presumably transitory.

Eldred (1970) described several leptocephali which she attributed to *Gymnothorax funebris*—the only representative of the family in the Mid-Atlantic Bight. Her figures and descriptions are included in the present volume, although David G. Smith (personal communication) has questioned their identity on the basis of the reported myomere count (131–136) compared to the known vertebral count for *G. funebris* of 139–145.

Gymnothorax funebris Ranzari, Green moray

ADULTS

Teeth $\frac{\text{ca. }32}{26}$,[2] vertebrae 139–145 (DGS).

Head 7 times in TL.[2]

Body elongate,[2] somewhat rounded in cross-section anterior to vent, moderately compressed posterior to vent (FDM); head conical; mouth terminal; nasal pits circular, the anterior ones almost terminal, the posterior ones just in front of eyes. One or more long depressible canines in midline of upper jaw, about halfway between snout

and eye; 2 rows of smaller teeth on vomer, with ca. 8 teeth in each row. Gill openings short, oblique. Body and fins covered with thick leathery skin. Dorsal fin origin slightly in front of gill opening. Pectoral and pelvic fins absent.[2,8,9,12]

Pigmentation: Body bright green to brown, olive brown, or slate gray;[2,8,9,12] green color due to yellowish mucous layer overlaying skin,[5] this layer lost in preservation or with rough handling (FDM); throat paler. Body sometimes slightly mottled; head sometimes with dark horizontal lines on lower parts. Dorsal and anal fin reported both with[2,8,9,12] and without dark longitudinal lines.[5]

Maximum length: 1893 mm.[11]

DISTRIBUTION AND ECOLOGY

Range: In the Atlantic, Canada to Rio de Janeiro, Brazil; Bermuda; Cape Verde Islands. Also reported from the eastern Pacific.[2,4,11]

Area distribution: Coast of New Jersey.[3]

Habitat and movements: Adults—coral reefs,[7] rocky shorelines,[5] sometimes in caves and cracks;[10] also reported from tidal creeks;[5] over bottoms of dead coral, sand and mud,[6] occasionally taken on grass beds where hard substrate is present (FDM). Maximum depth, 12 m;[5] minimum depth, 20 cm (FDM).

Leptocephali—recorded from waters of Florida Straits; reported salinity range 37.0–38.5 ppt; reported temperature range 28.0–28.5 C.[1]

Elvers and/or juveniles—inshore in Puerto Rico in April,[13] or year round but sporadic (FDM).

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LEPTOCEPHALI

Size range described, 10.8–29.5 mm, the largest specimen thought to be transitional.

Total myomeres 131–136; preanal myomeres 75–77; postanal myomeres 56–59. Teeth $\frac{1+\text{II–III}+1\text{–}4}{1+\text{I–III}+1\text{–}2}$.[1]

Proportions as percent TL: Preanal length 74; maximum depth (at anus) 13; head length 6.[1]

Eye with narrow, fleshy margin. Dorsal fin origin at myomeres 54–57; myomeres between dorsal and anal origin +13−23. Caudal fin rays undeveloped. A small pectoral fin evident,[1] this lost later (JDH). Twenty-three myomeres before anus; anterior margin of liver between myomeres 13 and 16; posterior margin of liver between myomeres 22 and 23; anterior margin of gallbladder between myomeres 20 and 22; first major vertical artery at myomere 18–20; renal artery at myomere 63–68; renal portal vein at myomere 69–73.[1]

Pigmentation: At 25 mm a series of chromatophores along dorsal midline between myomeres 10 and 54; a second series along dorsal surface of intestine past liver; and a third series along ventral surface of spinal cord. Two conspicuous single chromatophores: one deep in myelencephalon and one below gill opening. Scattered chromatophores on palate and on ray bases of dorsal and anal fins. Eyes pigmented.[1]

ELVERS

No information.

JUVENILES

Minimum size, unknown.

Pigmentation: Olivaceous or dark brownish gray,[11] uniform.[5]

AGE AND SIZE AT MATURITY

No information.

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Conger oceanicus

conger eels
Congridae

FAMILY CONGRIDAE

The family Congridae, which contains three subfamilies and about 38 genera and 100 species, occurs only in the Atlantic and Pacific oceans. The only regional representative of the family (*Conger oceanicus*) has been recorded as far north as Nova Scotia. Members of the family are generally limited to shallow, coastal waters. In the Atlantic, they typically occur over sandy bottoms near grass beds and reefs.

In this family the pectoral fins may be well-developed (as in Congrinae) or minute or absent (as in Heterocongrinae). Congridae are scaleless. The lateral line is present; the nostrils are lateral and in front of the eyes; the anterior nostril is developed as a short tube; the mouth is usually almost horizontal.

Little is known of the spawning of *Conger oceanicus* except that it apparently moves offshore to spawn. *Conger conger* ceases feeding before spawning; its teeth are lost. There are radical changes in the shape of the head, the bones become soft and gelatinous, and the eyes of the males become greatly enlarged. The fish die after spawning.

Offshore spawning migrations may be typical of a number of congrid eels. Females of *Ariosoma bowersi* become egg-bound in captivity, swell to enormous dimensions, and eventually explode. This results from the presence of a calcareous plug in the oviduct which, presumably, may not form if the females are exposed to increased pressure in offshore waters.

Congrid leptocephali may have from 106–242 myomeres (140 to 151 in the regional species), and the gut, which lacks swellings, may extend almost to the end of the body. Leptocephali of some members of the family have narrow eyes beneath which there is a distinct patch of choroid tissue. In the subfamily Congrinae (to which *Conger oceanicus* belongs) there is usually a prominent pigment patch beneath the eye and pigment ventrally below the gut. Characteristics for distinguishing congrid leptocephali from other regional *leptocephali* are presented in a key in the introduction to the section on Ophichthidae.

Schmidt (1931b) pointed out that the eggs and larvae identified by Eigenmann (1902) as *Conger oceanicus* were, in fact, those of an ophichthid eel. The specific identity of this series, based on eggs collected off New England, is still unknown.

Conger oceanicus (Mitchill), Conger eel

ADULTS

D. 273; A. 187; P. 16–18; [12] branchiostegal rays 9; [15] total vertebrae ca. 135 [12]–149 [20] (but note higher larval myomere counts below); precaudal vertebrae 50–51; caudal vertebrae 85–96; lateral line pores 39–44; compressed teeth in upper jaw 27–65, in lower jaw 28–59.[12]

Head 6.37–7.30 times in TL; depth 2.3–2.85 times in head.[2] Length of head as thousandths of TL, 130–180.[12]

Body elongate, round anteriorly, compressed posteriorly.[2] Upper jaw usually projected beyond lower; [1] two rows of teeth, the innermost conical; premaxillary tooth patch wider than long.[12] Skin scaleless. Eyes oval.[1] Lateral line complete.[2] Origin of dorsal less than 50 percent of pectoral fin length behind tip of pectoral.[12]

Pigmentation: Grayish brown, bluish gray or nearly black above, sometimes with reddish tinge; sides paler; dingy white below. Dorsal fin light blue centrally, dusky at base, and with black outer edge; anal pale, edged with black; pectorals blue gray, tipped with bluish white or pale blue.[1,2,15]

Maximum length: Possibly to ca. 2034 mm.[1]

DISTRIBUTION AND ECOLOGY

Range: Coastal waters from Nova Scotia [13] to Mississippi; [12] also the West Indies based on collections of larvae.[1] Records from Brazil [9,11] are questioned (JDH).

Area distribution: Lower Chesapeake Bay north to Worcester County, Maryland and mouth of Potomac River; [2,4,6,26] coastal waters of New Jersey and Delaware.[7,12]

Habitat and movements: Adults—waters of the continental shelf, sometimes entering harbors, sounds, shallow bays, and river mouths along coast; [1,11,17,19] minimum salinity, 22.3 ppt; [21] maximum depth, 475 m.[12] Possibly moves offshore in winter or during spawning season.[1,5]

Leptocephali—coastal and estuarine waters from Nova Scotia to Chesapeake Bay; [1,3,13] in northern latitudes inshore (and sometimes washed on beaches) from May to August; [8,10,18,22,30] minimum salinity, in water which varied annually from 3 to ca. 19 ppt,[14] also in estuarine water with average of 26 ppt.[30]

Elvers and/or juveniles—recently transformed individuals from Fire Island Inlet, Long Island in August.[27]

SPAWNING

Location: Possibly offshore in New England; [1,5,20] also thought to spawn in the West Indies.[1]

Season: Possibly summer in New England; [1,5] leptocephali collected as early as late May in Long Island [22] and mid-July in Nova Scotia; [13] in aquaria adults ripen in all months except October and November.[20]

Fecundity: Unknown (counts attributed to this species [24,25] are based on *Conger conger* [23]).

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LEPTOCEPHALI

Maximum length attained, 160 mm. Specimens 75 [29]–98 mm [30] long have apparently shrunk from maximum size and begun transformation.

Total myomeres 140 [1]–151; [8] preanal myomeres 74; postanal myomeres 72; [29] myomeres before dorsal (at 96.5 mm) 52. [8]

At 96.5 mm TL head 4.6 mm, eye 1.7 mm, body width 6.6 mm.[8]

Eye oval, pectoral fins formed at 96.5 mm.[8]

Pigmentation: At 93.0 mm TL a crescentic pigment patch under eye.[31] At 96.5 mm, in life, perfectly transparent, eye brilliant gold; after preservation, a row of about 85 minute dots along side of body, ca. 100 similar dots along ventral surface, numerous small dots at bases of anal and dorsal rays.[8] In an apparently more advanced specimen 75 mm long pigment differentiation along outer edge of fins.[29]

ELVERS

No information.

JUVENILES

Size range described ca. 107 [18]–150 mm.[12]

At ca. 113 mm body elongate, tapering posteriorly to a

point, very compressed.[16]

At ca. 150 mm number of teeth less than in adult.[12]

Pigmentation: At ca. 113 mm translucent, vertebral column and ribs visible, small spots on margin of dorsal and anal fins and along lateral line.[16]

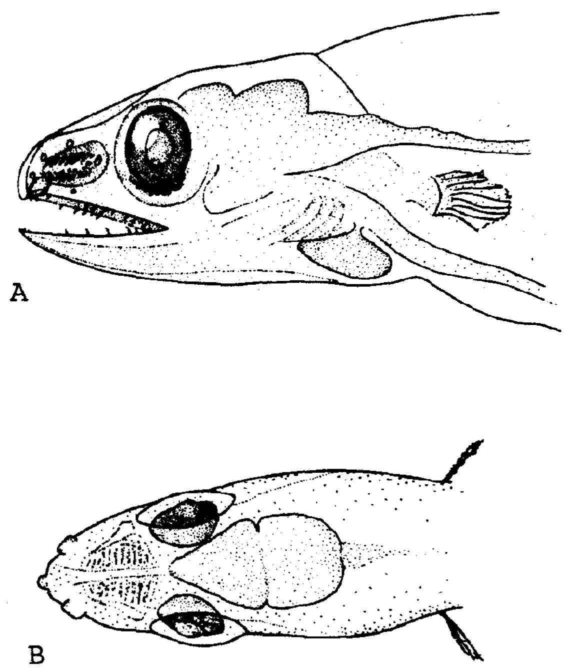

Fig. 12. *Conger oceanicus*, Conger eel. Head of transforming leptocephalus, 93.5 mm TL. A. Lateral view. B. Dorsal view. (*A, B, Original illustrations, Daniel M. Carver.*)

AGE AND SIZE AT MATURITY

No information.

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Ahlia egmontis
Myrophis punctatus
Ophichthus gomesi
Ophichthus ocellatus
Pisoodonophis cruentifer

snake eels
Ophichthidae

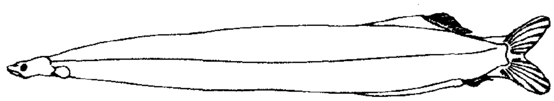
FAMILY OPHICHTHIDAE

Members of this family are most easily distinguished from other eels by the position of the posterior nostril which either pierces the upper lip or lies along the inner margin of the lip within the mouth. In addition, they are characterized by their attached tongue and by the presence of a distinct jugostegalia in the throat formed by overlapping of the branchiostegal rays. Most ophichthid eels lack pectoral fins, and some have no fins at all. Two subfamilies are recognized: Ophichthinae (snake eels) and Echelinae (worm eels). Snake eels lack scales and an external fin around the tip of the tail, their tail tip is strong and spike-like, and, typically, they have striking and sometimes very bright color patterns. In worm eels there is a fringe-like fin around the tip of the tail, and

A key to leptocephali of Mid-Atlantic Bight fishes:

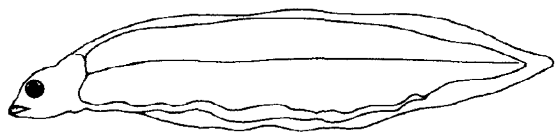
1A. More than 100 myomeres 2

1B. Less than 90 myomeres; anus far back on body; distinct dorsal, anal, and caudal fins formed during development of leptocephali . Order Clupeiformes: Elopidae and Albulidae (see volume I).



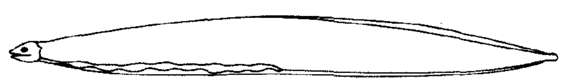
2A. Total myomeres 114 or more 3

2B. *102–110 myomeres, preanal myomeres 63–74,* preanal length 60–74 percent TL, no pigment on body, gut without "loops" or swellings .... *Anguilla rostrata*

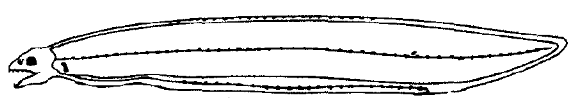


3A. Gut straight, lacking swellings or "loops" 4

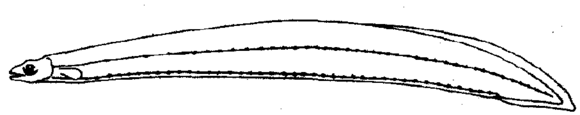
3B. Gut with 3–11 distinct swellings or "loops" 5



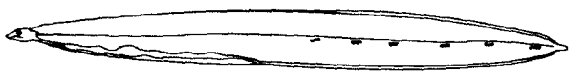
4A. Total myomeres 131–136; preanal myomeres 75–77; pectoral fin rudimentary, never well-developed; no pigment below eye .... *Gymnothorax funebris*



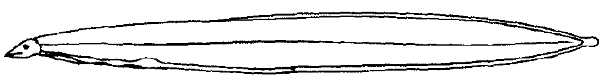
4B. Total myomeres 140–151, preanal myomeres 74, pectoral fin well-developed by end of stage, usually a crescent-shaped pigment patch below eye .... *Conger oceanicus*



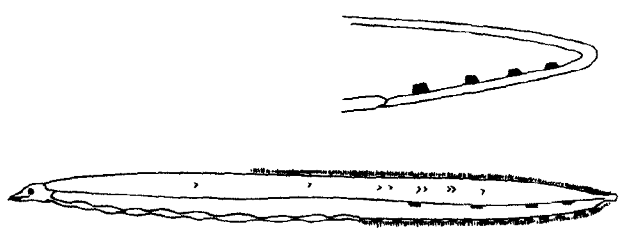
5A. Gut with less than 8 swellings or "loops" 6
5B. Gut with 8 or more swellings or "loops" 7
6A. 4 to 6 gut swellings, 4–7 subcutaneous spots below midline on tail, total myomeres 147–165, preanal myomeres 65–73 .... *Ahlia egmontis*



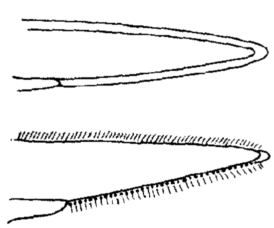
6B. 3 gut swellings, the third most prominent; no subcutaneous spots ventral to midline on tail, total myomeres 138–150, preanal myomeres 52–63 .... *Myrophis punctatus*



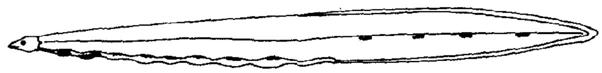
7A. A series of conspicuous, evenly spaced, linear pigment clusters separated by unpigmented gaps ventrally beyond anus and, in later stages, this pigment associated with developing anal fin; pigment present on a few myosepta between mid-lateral line and dorsal ridge (but not shown in all illustrations in present account); 8 or 9 prominent spots on gut; total myomeres 114–162; preanal myomeres 66–75 .... *Pisoodonophis cruentifer*



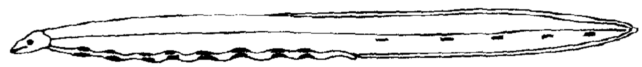
7B. No pigment ventrally beyond anus, or a single chromatophore at base of each anal fin ray 8



8A. Gut with 8 weak swellings, ventral gut pigment restricted to first 2 swellings, total myomeres 139–150, preanal myomeres 66–79 .... *Ophichthus gomesi*



8B. Gut with 9 weak swellings, gut pigmented ventrally throughout its length, total myomeres 126–142, preanal myomeres 62–78 .... *Ophichthus ocellatus*



Ahlia egmontis (Jordan), Key worm eel

ADULTS

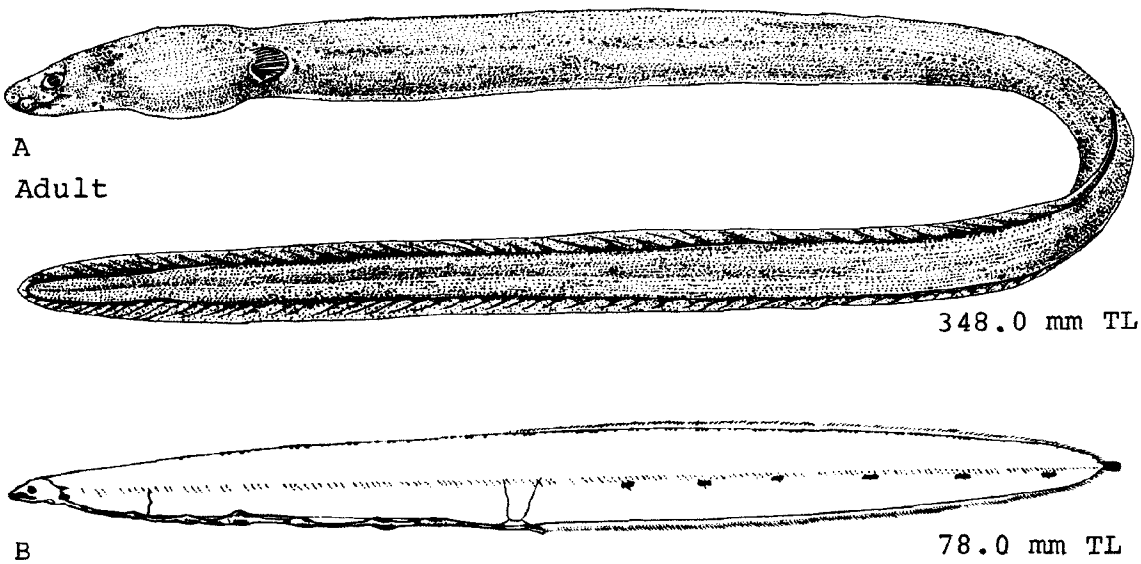
(The following based on a sample of about 20 specimens.) Preanal fin vertebrae 63–66, predorsal vertebrae 65–70, total 157–162 (JEB) or 152.[13]

Proportions as percent TL: Head 9.2–9.6, body 42.3–44.4, trunk 32.6–34.8, tail 55.5–57.6, snout 1.6–1.9, eye 0.5–0.6, depth 2.4–2.5, upper jaw 2.4–2.5, lower jaw 2.2–2.3.[7] Distance from snout to dorsal 2.1–2.5 times in TL, depth 2.6–3.0 times in head,[9] eye 1.3–2.3 times in snout.[10]

Body slender, compressed;[10] head small, moderately pointed, anterior nostril in a short tube; lower jaw considerably shorter than upper; gape extended beyond eye;[6] eye relatively small, but apparently increasing in size during spawning season as in *Anguilla*.[2] Dorsal origin above or slightly behind anus;[4,10] caudal and pectoral fins developed[5] (in specimens 215–270 mm long, pectorals short and broad, about as long as snout and broader than gill slit).[9]

Pigmentation: Variable. May be almost uniformly pale, may have upper half finely peppered with dark dots, may be bicolored (upper half dark, lower half light) in trunk region with tail uniform throughout, or may be entirely brown except for ventral surface of trunk region.[4] Pigment also described as yellowish, brownish[5,10] or olive green above, bright golden yellow to yellowish olive below. Fins light yellowish.[11]

Maximum length: 381 mm.[4]



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DISTRIBUTION AND ECOLOGY

Range: From just south of Martha's Vineyard, Massachusetts [1] (based on leptocephali) to Maceió, Brazil; [3] also the Bahamas [4] and the West Indies.[11]

Area distribution: A single leptocephalus from the coast of New Jersey.[1]

Habitat and movements: Adults—primarily a shallow water species [2] (although apparently move seaward at certain times of year [8]) found over hard bottoms [5] and reefs; [4] specifically recorded from canals, natural channels, tidal creeks, protected bays, eel grass beds,[2] and over fine white sand; [7] may burrow in substrate; [2] nocturnal, often swimming at surface at night. Apparently move seaward on ebb tide in late fall and early winter, and this movement may be associated with spawning.[2,8]

Recorded depth range, 6 or 7 cm [2] to 37 m.[9] Temperature range 26.5–31.0 C. Maximum recorded salinity, 35.5–35.7 ppt.[1]

Leptocephali—oceanic; recorded temperature range 20–28.7 C.[1]

Elvers and/or juveniles—no information.

SPAWNING

Location: Probably pelagic [4] in deep water beyond the continental shelf of North America, and in the Caribbean.[1]

Season: Unknown, except for comment that seaward movement in late fall and early winter is probably associated with spawning.[2,8]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LEPTOCEPHALI

Size range described 56 [1]–85 mm TL.[12]

Total myomeres 147–165, preanal myomeres 65–73,[1] postanal myomeres 89–93; [12] maxillary dental formula 0–1 + II–V + 0–7.[1]

Relative preanal length decreases from 53% TL at 56.0 to 48% at 82.0 mm.[1]

Body long, slender, tapering from very slender head to behind alimentary canal.[12] Dorsal fin origin at myomere 63–70. Gut swollen at 4–6 places (although usually 4); first gut swelling at about myomere 17; third gut swelling pronounced; fourth and fifth and sixth (if present) low and indistinct. Anterior margin of liver at myomere 13–18, posterior margin at myomere 21–32. First major artery joins aorta at myomere 16–24, renal artery at myomere 62–66, renal-portal vein at myomere 68–71. Opisthonephros located over gut, and with 2 peaks on dorsal aspect.[1]

Pigmentation: In specimens 56.0–82.0 mm TL nearly

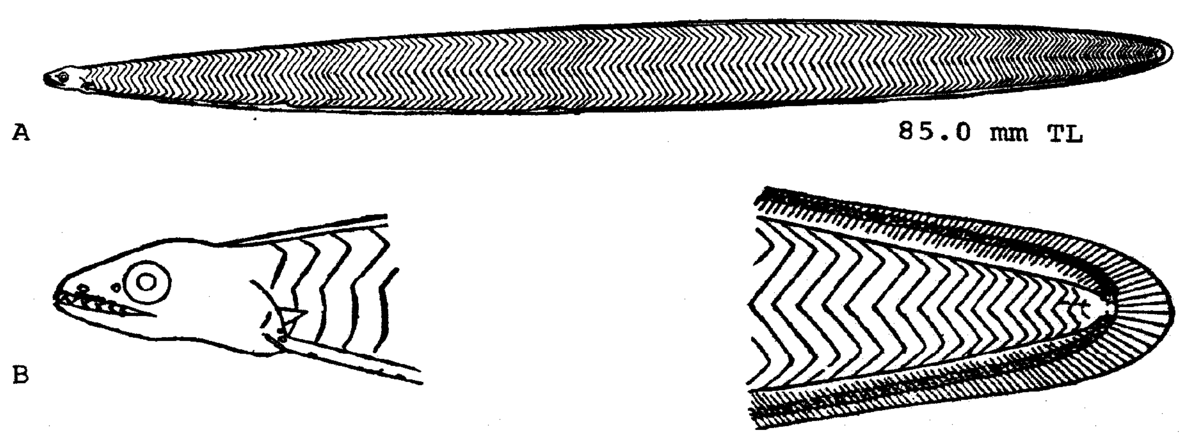


Fig. 15. *Ahlia egmontis*, Key worm eel. A. Leptocephalus, 85.0 mm TL. B. Detail of head and caudal region of A. (*A, B, Eigenmann, C. H., and C. H. Kennedy, 1901: fig. 14.*)

every myoseptum with a series of dashes just ventral to midline; 4–7 subcutaneous spots below midline, on tail; gut pigmented on dorsal and ventral aspects at level of each swelling and on dorsal aspect near anus; a series of spots along dorsal edge of body; anal base with a single spot at base of each ray; few small spots on gular region and snout.[1]

surface when preserved.[9] A 159 mm specimen described as yellowish brown.[11]

AGE AND SIZE AT MATURITY

No information.

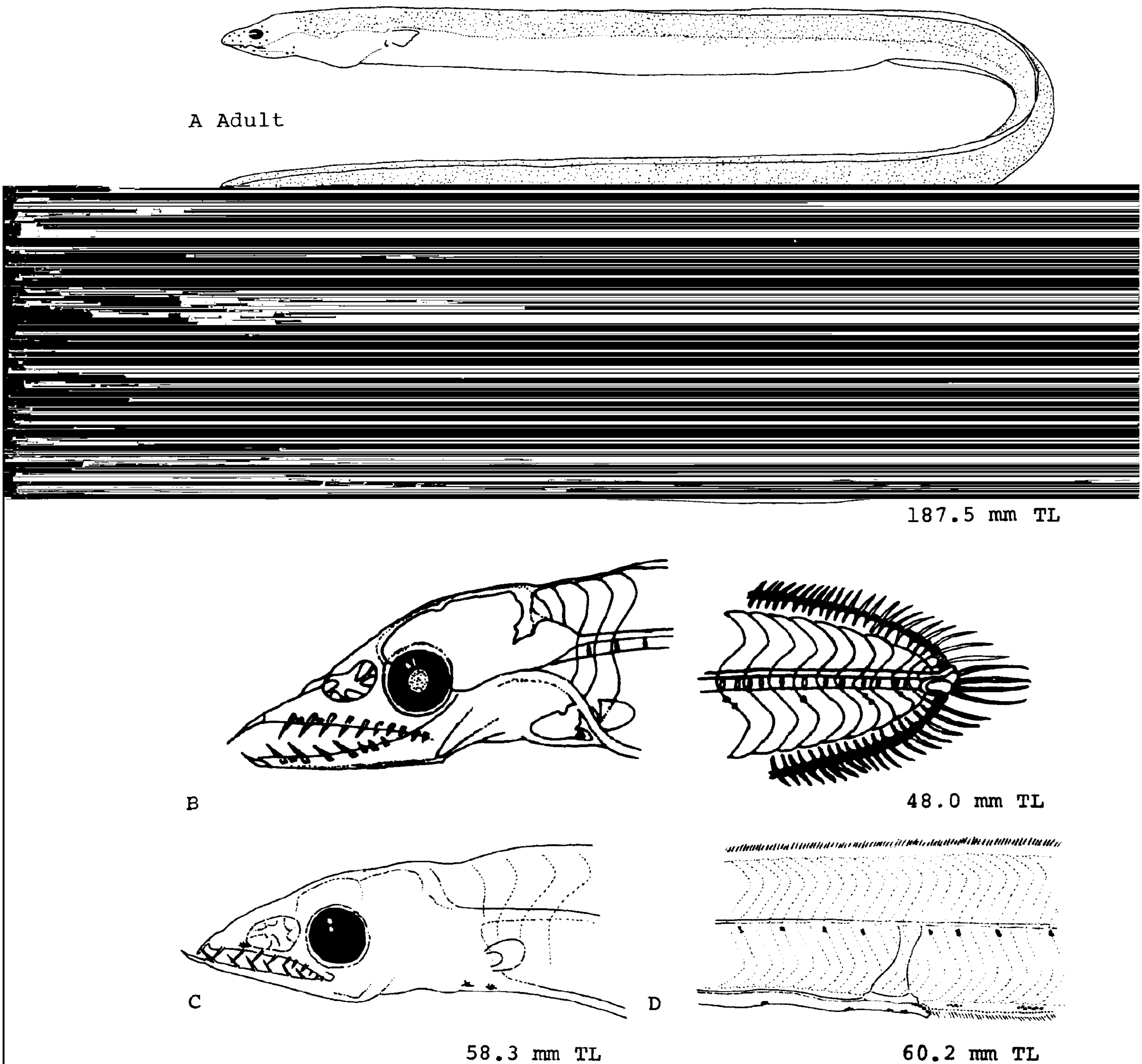
Myrophis punctatus Lütken, Speckled worm eel

ADULTS

Vertebrae (based on myomere counts of young) 138–150.[1,16,17,19,30] Head 3.0[28]–3.5 times in trunk, 5.5 times in tail.[21] Depth of body at gill opening 2.75[28]–3.3 times in head,[21] 25–35 in TL (MPF). Distance from dorsal origin to anus 1.9–2.6 times in trunk.[3]

Body worm-like, slender, compressed or rounded,[2] upper jaw projected,[14] snout somewhat broader than long,[24] gape extended beyond eyes.[29] Posterior nostril large, located at rim of gape; anterior nostril tubular, near lateral profile and a short distance from end of snout.[3] Eye ellipsoid.[13] Teeth small, pointed; teeth on upper jaw usually in 2, rarely 3, irregular rows; premaxillary teeth usually 5 in number and in an arched row; palatal teeth in 2 or 3 rows.[3] Tongue attached.[13]

Vertical fins high (MPF); origin of dorsal fin halfway



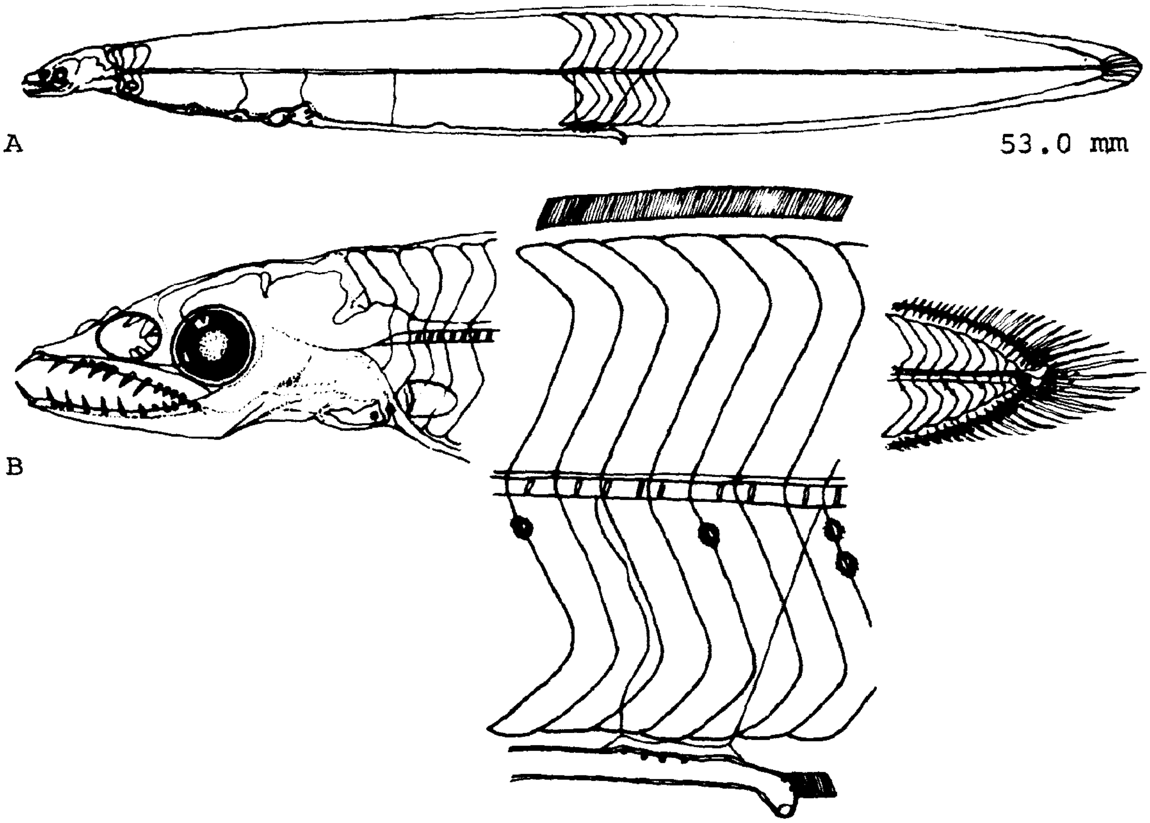


Fig. 17. *Myrophis punctatus,* Speckled worm eel. A. Stage I leptocephalus, 53.0 mm TL. B. Detail of head, midbody and caudal region of previous specimen. (*A, B, Eldred, B., 1966: fig. 2.*)

between gill opening and anus; [2] pectoral base wide (MPF).

Pigmentation: Brownish or yellowish; anterior lower half nearly uniform in color; dorsal surfaces covered with tiny dark specks, with speckled pattern covering most of sides posteriorly.[3] Iris pale.[13]

Maximum length: 426 mm.[3]

DISTRIBUTION AND ECOLOGY

Range: Chesapeake Bay, Maryland [2] to Rio Goyanna, Brazil; also Bermuda,[4] the West Indies,[1] and the west coast of Africa.[13]

Area distribution: A single specimen from Chesapeake Bay, off Calvert County, Maryland [2] (the inclusion of this species among the Potomac River ichthyofauna [25] is questioned, JDH).

Habitat and movements: Adults—a coastal species (JDH) sometimes entering bays [23] and tidal creeks,[6] usually over soft mud; [1,3,8,23] sometimes over dead coral and sand; minimum depth less than 1.2 m; [6] maximum depth, 88 m; [12] temperature range 16–33 C; euryhaline,[26] salinity 17–37 ppt.[11] Move to surface at night; [1] in some areas move in and out on flood and ebb tides each day; [15] in Louisiana inshore in spring and fall; [9] in Florida move seaward on night ebb tides in late fall and winter.[23]

Leptocephali—coastal, in both offshore and inshore waters (JDH), sometimes entering shallow bays; found at surface at night; temperature range 12.2–26.0 C; [1] salinity range 0.0 [22]–39.5 ppt. Leptocephali recorded offshore in January, February, March, June, November, and December; inshore in January, February, March, October, November, and December.[1,27]

Elvers and/or juveniles—elvers recorded both inshore and offshore; initially planktonic,[1] but cease planktonic existence between March and May,[32] burrowing then into mud; also reported along grassy shores,[1] at surface at night.[11] Reported inshore from December through May, occasionally offshore in March [1] and August.[30]

SPAWNING

Location: Offshore,[1] probably beyond the 46 m contour.[26]

Season: Probably fall and winter, "larvae" recorded from October through March, but most prevalent in December and January.[1]

Note: *Spawning males may acquire larger eyes and pectoral fins.*[6]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LEPTOCEPHALI (STAGED)

Stage I (size increasing): Size range 48 [1]–80 mm.[26]

D. 337. A. 233. Total myomeres 138–147 (average 141); preanal myomeres 54–59 (average 55); postanal myomeres 82–91 (average 86); myomeres between D. and A. 21–26 (average 23). Dorsal origin at myomere 30–35 (average 32); anterior margin of liver at myomere 12–14 (average 13), posterior margin at myomere 21–27 (average 24); first major artery at myomere 18–22 (average 19), 2nd at 24–27 (average 25), 3rd at 28–36 (average 32); major renal artery at 49–55 (average 51); renal-portal vein at 54–59 (average 56).[1]

Proportions as percent SL at ca. 60–80 mm, dorsal 70–74, anal 55–56.[26]

Body long, flattened, tapering to maximum depth just behind anus. Snout described as thin and pointed,[1] or blunt. Eye distinctly oval in 71 mm specimen,[2] otherwise apparently round.[1] Gape to posterior edge of pupil.[2] Gill slits small, oblique. Leptocephali up to 59.8 mm with unseparated nasal capsule. Teeth in upper jaw 0–1 + 0–VI + 0–11; in lower jaw 0–1 + III–IV + 0–4.[1] Anteriormost lower tooth almost horizontal.[2] Pectoral fins small, rounded, located at 3rd myomere; pectoral rays developed in a specimen 59.8 mm long,[1] although absent in other specimens up to ca. 80 mm long.[2]

Pigmentation: Transparent throughout stage. Lateral pigment spots variable (MPF); in some descriptions lateral series of paired brown chromatophores under the and comprised of 1 or 2 large chromatophores over every 3rd [1] to 6th myoseptum; the total series consisting of ca. 36–40 pairs of spots. In some specimens the last 4–6 spots broken into clusters of smaller dots.[26]

Stage IIa (size decreasing): Size range 79.0–ca. 50.0 mm.[1]

Total myomeres 138–148 (average 142); preanal myomeres 53–59 (average 55); postanal myomeres 83–90 (average 86); myomeres between dorsal and anal 20–26 (average 23); branchiostegals, when present, 5–7.[1]

Dorsal origin at myomere 30–37 (average 32); first major artery at myomere 17–21 (average 19), 2nd at myomere 22–30 (average 25), 3rd at myomere 29–36 (average 34); major renal artery at level of myomere 48–53 (average 51); renal-portal vein at myomere 53–59 (average 58); anterior margin of liver at myomere 11–15 (average 13), posterior margin at myomere 23–26 (average 24).[1]

Depth ca. 11 times in length at 74 mm.[7]

Body long, flattened. Nostrils well differentiated, the anterior ones becoming tubular. Teeth absent.[1] At 74 mm gape extending beyond eyes, lower jaw shorter than upper.[7]

Pigmentation: Transparent throughout stage. At 74 mm a lateral series of spots on myocomma, each spot consisting of 1 or 3 chromatophores; one or two chromatophores below pectoral; six prominent spots along alimentary canal with a few chromatophores scattered between them; a few spots along anal and caudal bases, and along bases of last dorsal rays; few chromatophores evident on head.[7] In "transition stage" ventral pigment spots tend to extend horizontally into longitudinal stripes; lateral spots somewhat enlarged.[26]

Stage IIb (size decreasing): Size range 62–ca. 45 mm. (Shrinkage of ca. 15–25 mm, average 19 mm, or ca. 26% SL, occurs during metamorphosis and transformation may take as little as 18 hours or less.) [26]

Total myomeres 138–146 (average 142); preanal myomeres 49–59 (average 52); postanal myomeres 85–93 (average 88); myomeres between dorsal and anal 19–25 (average 21); branchiostegal rays 4–7 and present in most specimens. Pectoral base at myomere 3–7; anterior margin of liver at myomere 11–14 (average 12), posterior margin at 23–25 (average 24); dorsal origin at myomere 29–37 (average 31). Head with series of mucous pores; snout rounded, blunt, extending beyond lower jaw. Anterior nostril near tip of snout, broad-based, tubular, and with pointed tab on upper part; posterior nostril on rim

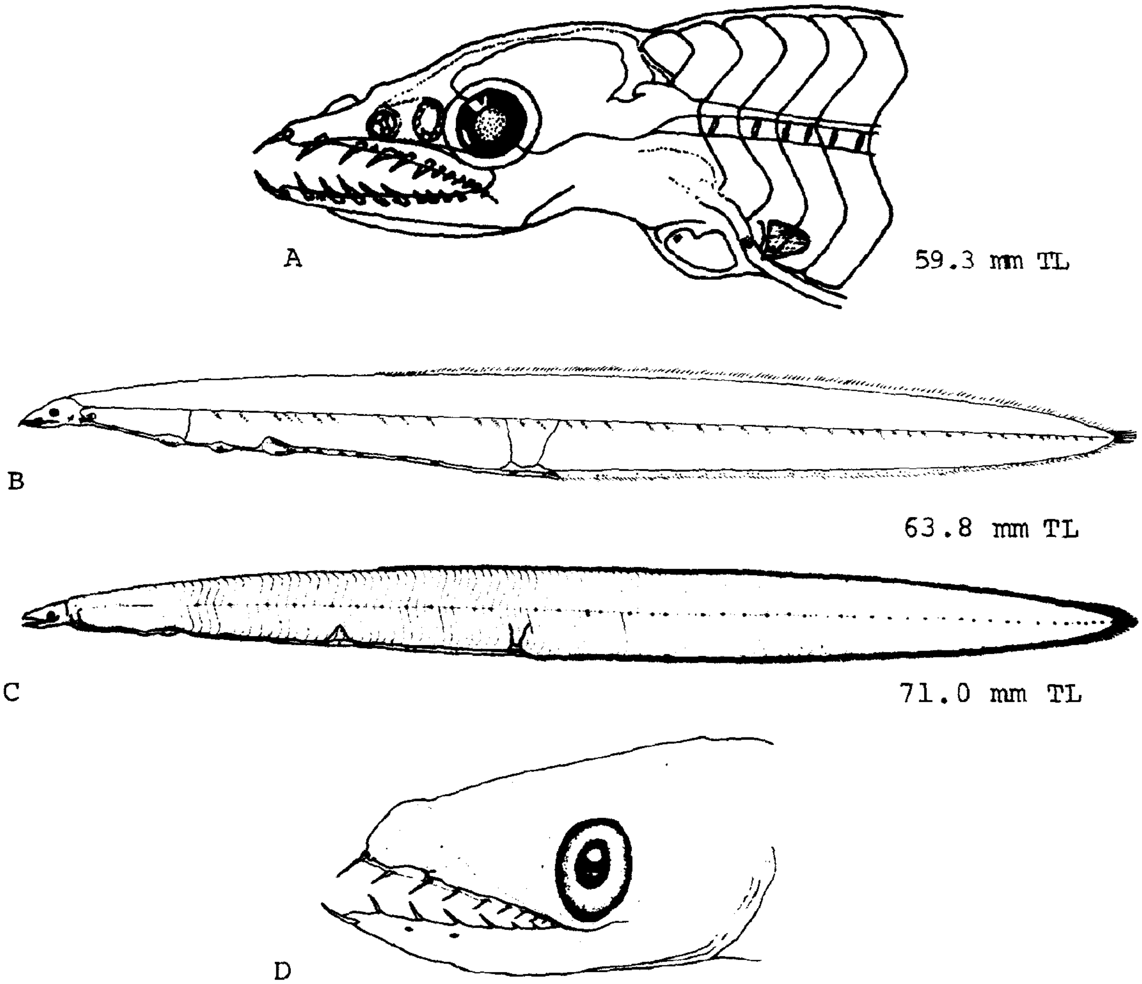


Fig. 18. *Myrophis punctatus*, Speckled worm eel. A. Stage I leptocephalus, detail of head of specimen, 59.3 mm TL. B. Stage I leptocephalus, 63.8 mm TL. C. Stage I leptocephalus, 71.0 mm TL. D. Detail of head of previous specimen. (*A, Eldred, B., 1966: fig. 3a. B, Fahay, M. P., and C. L. de Gorgue, MS. C, D, Cooper, J. E., and M. P. Fahay, 1974: 32.*)

Pigmentation: Opaque, otherwise undescribed.[1]

LEPTOCEPHALI (UNSTAGED)

22.5–78.2 mm TL, substages not distinguished.

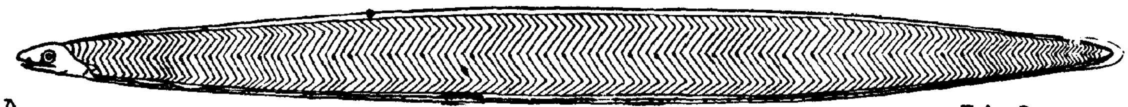
Total myomeres 138–150, preanal myomeres 52–63. Maxillary dental formula 0–1 + III–VIII + 3–7.[30]

Preanal length as percent TL: At 23.8 mm, 69%; at 78.2 mm, 44%.[30]

Anterior margin of liver at myomere 10–16, posterior margin at myomere 19–27; first major artery at myomere 13–20; renal artery at myomere 48–54; renal-portal vein at myomere 54–60; origin of dorsal fin at myomere 30–37. Three gut swellings, the third most pronounced. Opisthonephores short, located over end of gut, and with two peaks on dorsal surface.[30]

Pigmentation: No subcutaneous spots ventral to midline posterior to vent; myosepta sporadically pigmented along midline; gut pigmented on ventral aspect of first and second bulges, on dorsal and ventral aspects of third bulge, intermittently along straight portion of intestine.[30]

At ca. 40 mm linear clusters of large spots between myomeres and anal fin base; at ca. 50 mm (and until time of metamorphosis) an additional row of smaller spots, one at base of each anal ray.[30]



A

74.0 mm TL

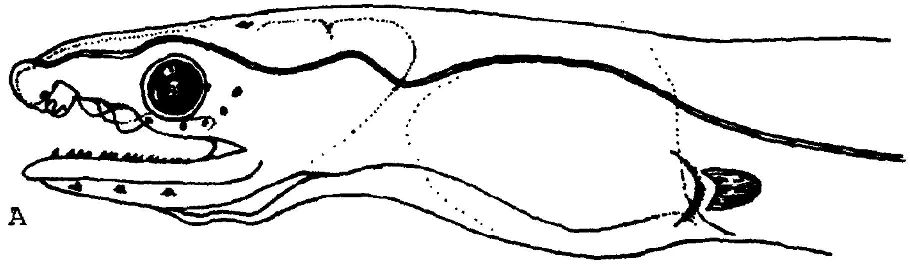


Fig. 20. *Myrophis punctatus*, Speckled worm eel. A. Elver, 49.0 mm TL. (*A, Eldred, B., 1966: fig. 3d.*)

ELVERS

Size range 39–59 mm.[1]

Average branchiostegals, 6.[1]

"Newly transformed" anal fin base length typically 55–56% SL, occasionally 39–40% (these later may represent either abnormally developing individuals or another species).[26]

Adult teeth developed.[1]

Pigmentation: No information.

JUVENILES

Size range described 121 [1]–146.[3]

Total vertebrae 138–145, preanal vertebrae ca. 45–53, postanal vertebrae ca. 86–93.[1]

Distance from dorsal origin to vent 2.0–2.4 times in trunk.[3] Proportions as percent TL in specimen 103 mm long: Head length, 9.7; snout length, 1.73; eye diameter, 0.75; snout to anal distance, 38.4; snout to dorsal distance, 23.8; pectoral length, 1.2; body depth, 2.4.[24]

Dorsal origin slightly more posterior in "young" than in adults.[13]

Pigmentation: A 120 mm specimen described as light olive-green with fine punctations above, lighter below.[21]

AGE AND SIZE AT MATURITY

No information.

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Ophichthus gomesi (Castelnu), Shrimp eel

ADULTS

Vertebrae 141.[14]

Proportions as percent TL: Head 10.8–11.7, body 34.9–40.2, tail 59.7–63.5, trunk 26.2–28.0, depth 4.0–5.0 [9] (depth also given as 20–30 times in length [6]), snout 1.8–2.8, upper jaw 3.8–4.9, lower jaw 3.1–4.5, eye 1.1–1.3.[9] Head 2.8 times in trunk; head and trunk 2 times in tail; [10] lower jaw 2.8–3.2 times in head; [17] pectoral fin 2 1/5 to 2 3/5 times in head.[8]

Conspicuous pores on head and jaws; [8] upper jaw overhanging lower.[7] Two to 4 rows of teeth on jaws and

sheared off by Carolina coastal current and carried southward.[16]

Elvers and/or juveniles—very small young at outlets of bays.[5]

SPAWNING

Season: Apparently in spring and summer [16] (adults captured in mid-July appeared to be recently spent [15]).

EGGS

Unfertilized eggs: Ca. 1.0 mm in diameter, pale yellow.[15]

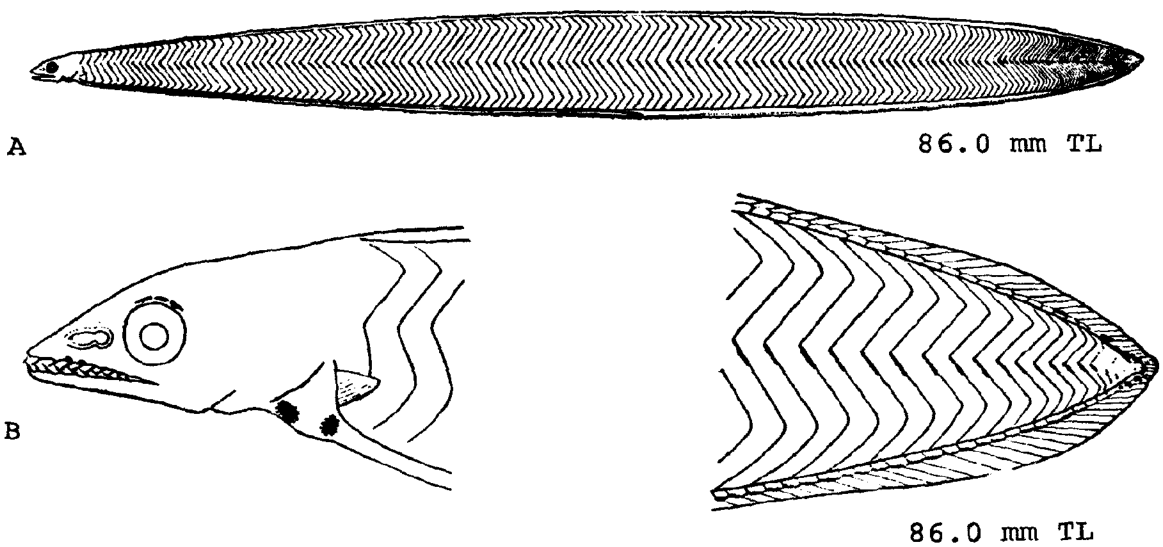

Fig. 22. *Ophichthus gomesi*, Shrimp eel. A. Leptocephalus, 86.0 mm TL. B. Detail of head and caudal section of A. (*A, B, Eigenmann, C. H., and C. H. Kennedy, 1901: fig. 9.*)

tip; few spots in gular region.[16]

In a specimen 86 mm long, pigment similar to above, but additional pigment as follows: several chromatophores at base of caudal, two at base of dorsal near tail, and 3–4 over eye.[17]

ELVERS

No information.

JUVENILES

Minimum size described, 211 mm.

At 211–238 mm jaw teeth in 2 rows, but outer row of mandibular teeth incomplete posteriorly.[13]

AGE AND SIZE AT MATURITY

No information.

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Ophichthus ocellatus (Lesueur), Palespotted eel

ADULTS

Vomerine teeth, ca. 15;[4] vertebrae, 134.[8]

[redacted]

row of lower jaw, except for a short distance anteriorly, smaller than those in outer row and variable in number from a nearly complete row to few; vomerine teeth usually in a single row, but sometimes two small teeth,

[redacted]

Pigmentation: Basic color variable, generally brown [3] or yellowish brown above,[5] yellow [7] or white below. Sides with series of 18 [5] to 21 [11] white spots running along entire length of fish.[7] Jaws, throat, and chin dusted with brown dots; [4] nuchal region often with a whitish rather narrow stripe anteriorly and a few irregularly scattered spots; [7] sides of head yellow; a longitudinal row of white dots on each side of head and a transverse one across top of head; [5] pores on head and lower jaw often marked with small brown spots.[7] Dorsal fin light colored with narrow dark edge, anal light yellow, pectoral dusky.[4]

Maximum length: Possibly to ca. 1830 mm, although identity questioned; [3] otherwise 815 mm TL.[5]

DISTRIBUTION AND ECOLOGY

Range: Adults from North Carolina to Brazil, including the Gulf of Mexico and the West Indies; [4,5,6,10] larvae north to Hudson Canyon (off New York).

Area distribution: Leptocephali recorded just south of Chesapeake Bay, and close to the 183 m line off New Jersey.[1]

Habitat and movements: Adults—typically over hard bottom,[3] but also recorded over mud.[5] Depth range 9 [7]–146 m.[3]

Leptocephali—some individuals drift south in the Carolina coastal current, while others are carried north by the Gulf Stream.[1]

Elvers and/or juveniles—no information.

SPAWNING

Season: Presumably at least 3 times a year, early winter, spring and early fall.[1]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LEPTOCEPHALI

Size range described, 11–87 mm TL.

Total myomeres 126–142, preanal myomeres 62–78,[1] postanal myomeres 56–58.[9] Maxillary dental formula 0–1 + II–VII + 3–9.[1]

At 42–59 mm greatest depth 13 times in TL; head ca. 1.25 times in greatest depth; eye 2 times in snout, 5.5 times in head.[9] Preanal length decreases from 81% TL at 19.0 mm to 59% TL at 77.5 mm.[1]

Body nearly uniform in depth from head to beyond end of alimentary canal. Snout pointed, profile straight or

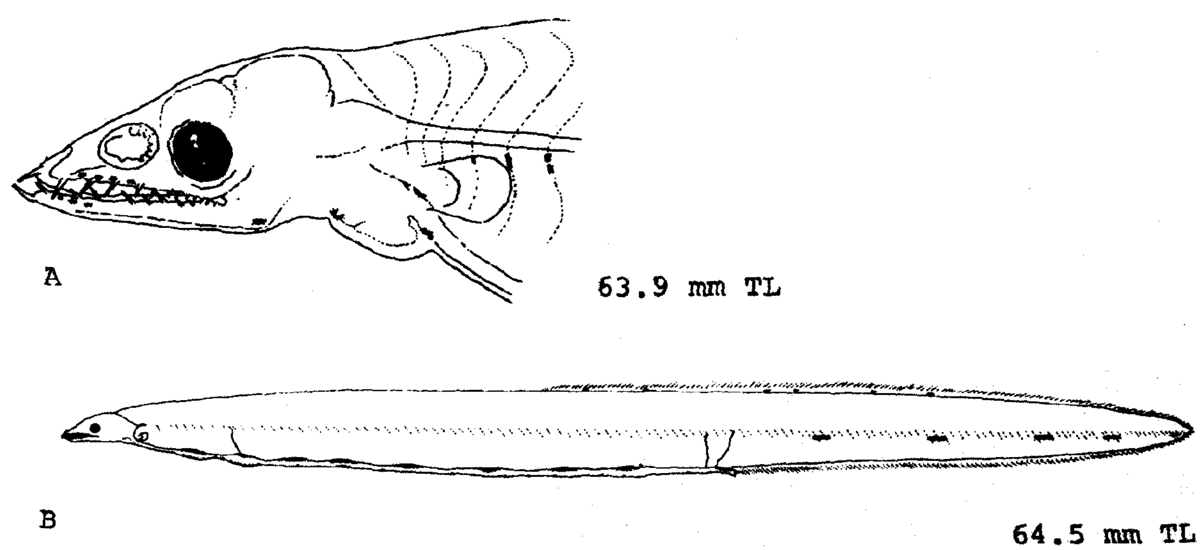

Fig. 24. *Ophichthus ocellatus*, Palespotted eel. A. Detail of head of 63.9 mm leptocephalus. B. Leptocephalus, 64.5 mm TL. (*A, B, Fahay, M. P., and C. L. de Gorgue, MS.*)

slightly depressed over eye. Anterior nostril about halfway between eye and tip of snout. At 42–59 mm pectoral fins well-developed;[9] dorsal fin origin at myomere 47–59. Gut with 9 weak swellings. First major artery leaves aorta at myomere 10–18, renal artery at myomere 57–63, renal-portal vein at 63–69. Anterior margin of liver at myomere 8–12, posterior margin at 19–22. Opisthonephros elongate.[1]

Pigmentation: In specimens 11–28 mm TL every myoseptum, except several of first few, with pigmented dashes just ventral to midline; gut pigmented ventrally with an accumulation of spots under first 2 swellings and sparsely on remaining length; gut pigmented dorsally with an accumulation of spots on each swelling; specimens over 45 mm with an additional two spots between first two swellings; four to six subcutaneous spots ventral to midline posterior to vent; anal base pigment absent in specimens less than 30 mm TL, sparse in specimens 33–35 mm TL, and with a single spot at base of every ray in specimens larger than 36 mm TL; pigment along dorsal edge of body in some specimens; 2 or 3 spots on lower jaw; 1 to 4 spots on upper jaw below bases of teeth; few gular spots present in all specimens.[1]

In another series of specimens 42–59 mm long, one or two chromatophores at margin of upper jaw; a series of 9 pigment spots above alimentary canal; no pigment spots at base of anal and dorsal fins; a few chromatophores at base of tail; a spot at upper surface of end of spinal cord; a series of ca. 4 spots in tail just beneath notochord; myomeres with 1–3 inconspicuous chromatophores below mid-lateral line.[9]

ELVERS

No information.

JUVENILES

Specimen described, 58 mm.

Preanal vertebrae 53, total vertebrae 137.[1]

Preanal distance 45% TL. Dorsal origin at vertebrae 14 and behind pectoral origin by distance equal to 2.5 times length of pectoral fin.[1]

Pigmentation: At 58 mm leptocephalous pigment no longer evident, head and body straw colored with an overlying scattering of dark spots.[1]

AGE AND SIZE AT MATURITY

No information.

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Pisoodonophis cruentifer (Goode and Bean), Snake eel

ADULTS

Total vertebrae 145–152, preanal vertebrae 61–62, postanal vertebrae 84–90.[6]

Depth 35–47 (MPF),[5] head 12 times in TL; eye 10 times in head.[8]

Body moderately elongate (MPF), more or less cylindrical, robust;[4] head snake-like, constricted behind;[9] snout conical, depressed,[10] bluntly rounded;[5] mouth ca. 1/3 length of head; upper jaw projected;[8] gape extended considerably beyond eye;[5] gill openings lunate.[8] Teeth very small, more or less compressed, short, robust, strong, pointed, biserial anteriorly on both jaws and vomer, slightly larger and more or less triserial on premaxillaries. Lateral line distinct, median.[4] Origin of dorsal a short distance behind tip of pectorals; anal origin far behind dorsal origin;[5] vertical fins low; pectoral fins narrow based (MPF); tip of tail hard, pointed;[5] no caudal rays.

Pigmentation: Uniform olive brown,[4] light brown or brownish yellow, or dorsal surfaces with alternating black and white mesh-like pattern;[8] large individuals darker than smaller;[5] inside of mouth white; dorsal fin pale to whitish, with anterior margin dark olive or brownish; anal fin pale to whitish; pectoral fin olive buff, darker along upper border.[4]

Maximum length: Ca. 416 mm.[2]

DISTRIBUTION AND ECOLOGY

Range: Reported from Cape Breton, Nova Scotia, but record based on specimen from swordfish stomach; otherwise Gulf of Maine to vicinity of Cape Henry, Virginia.[2]

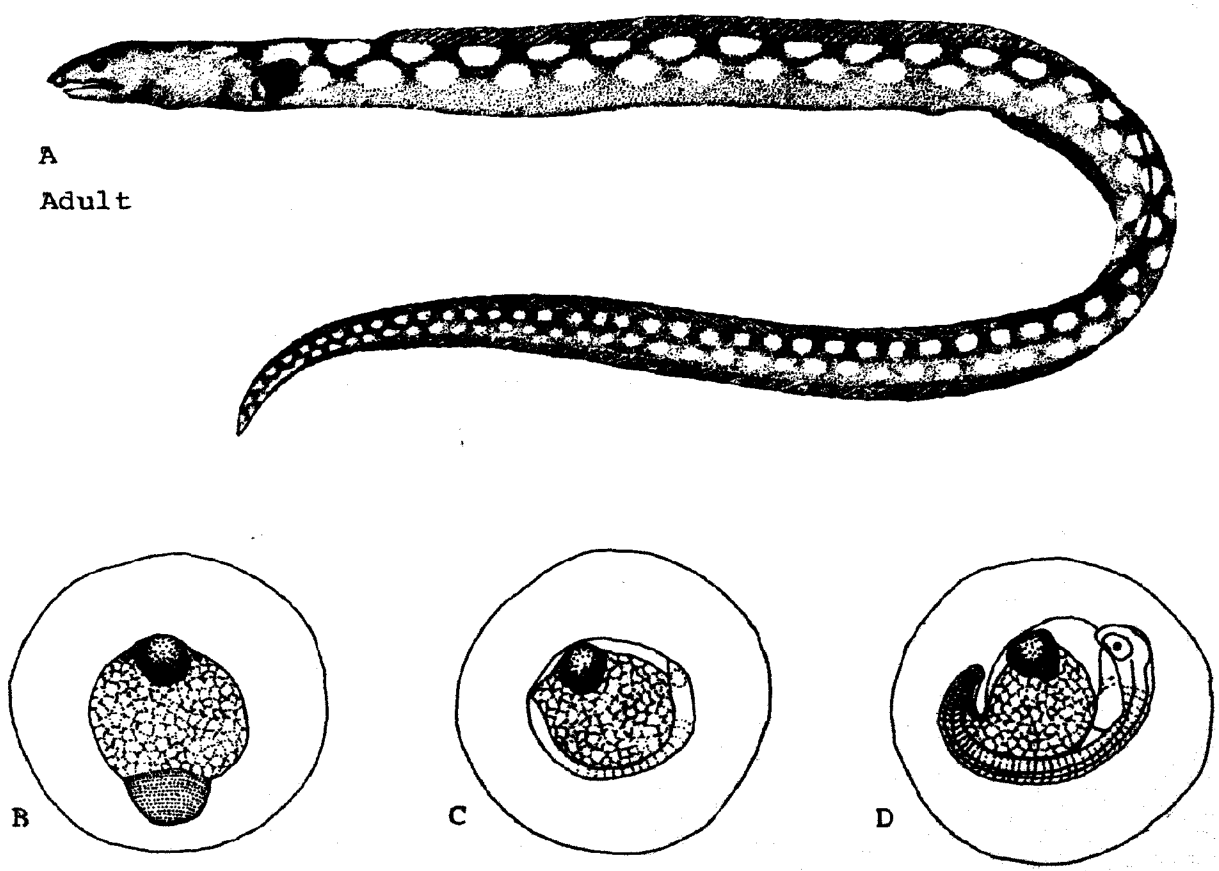

Fig. 25. *Pisoodonophis cruentifer*, Snake eel. A. Adult, size unknown. B. Egg at early stage of development. C. Embryo about two-thirds around yolk; eyes, somites forming. D. Tail-free embryo. (*A, Leim, A. H., and W. B. Scott, 1960: 162. B-D, Richardson, S. L., 1974: fig. 1.*)

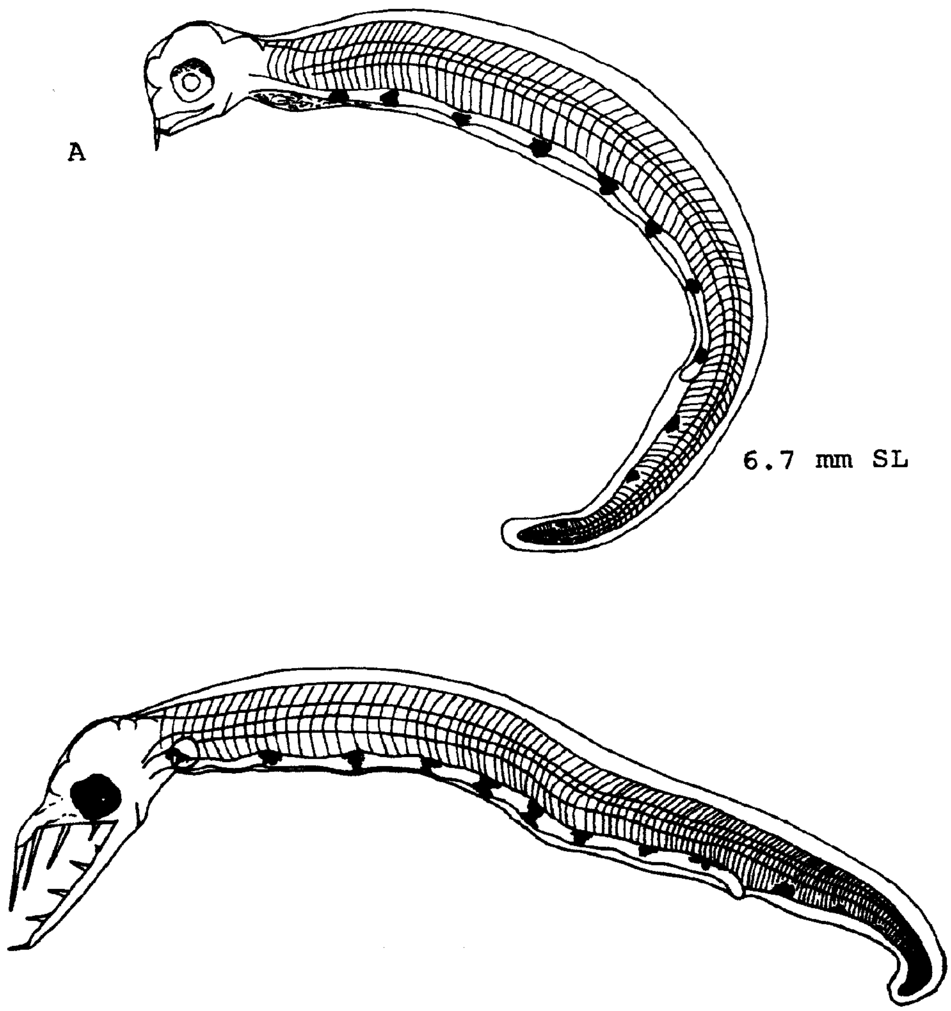

Fig. 26. *Pisoodonophis cruentifer*, Snake eel. A. Leptocephalus, 6.7 mm SL. B. Leptocephalus, 6.9 mm SL. (*A, B, Richardson, S. L., 1974: fig. 2.*)

Pigment also described as follows (size range 13.0 to 83.5 mm TL): pigment along dorsal edge of body; myosepta sporadically pigmented with few dashes ventral to midline; flank pigment present on upper angle of a few myosepta between midline and dorsal edge of body and on lower angle of a few postanal myosepta between midline and ventral edge of body; extent of flank pigment increases in specimens from ca. 50 mm TL to ca. 79 mm TL when the flank pigment becomes faint; prominent pigment spots along dorsal edge of body; gut pigmented on and between swellings, on dorsal as well as ventral aspects; anal base pigment in short, linear clusters separated by unpigmented gaps; 5 to 7 subcutaneous spots ventral to midline, posterior to vent; spots on head, snout, lower jaw, and gular area all increase in extent and intensity with growth.[12]

JUVENILES

Minimum size described (although stage uncertain): 65 mm.

Pigmentation: At 65 mm pale with dark speckles.[5]

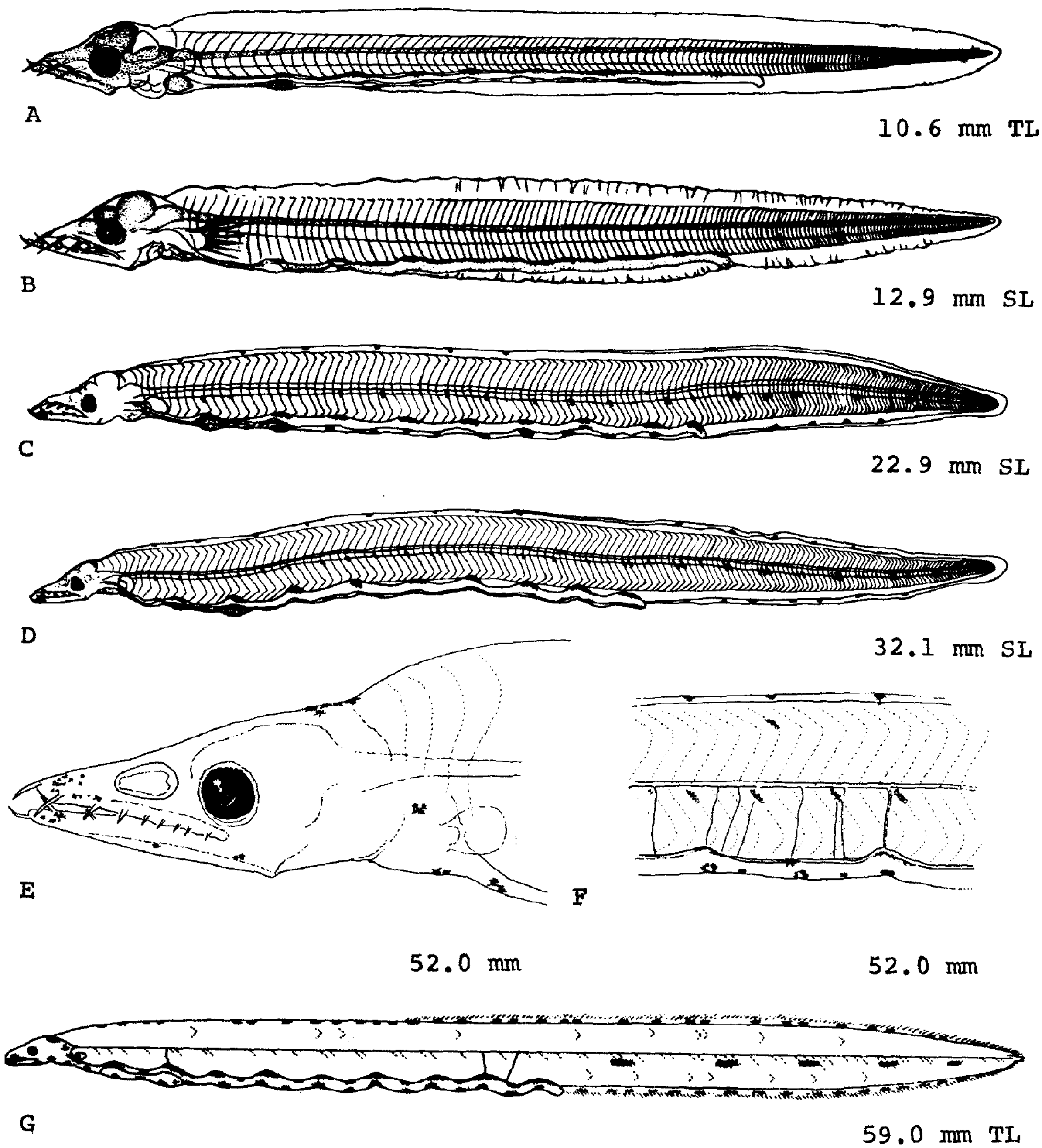

Fig. 27. ***Pisoodonophis cruentifer,*** Snake eel. A. Leptocephalus, 10.6 mm TL. B. Leptocephalus, 12.9 mm SL. C. Leptocephalus, 22.9 mm SL. D. Leptocephalus, 32.1 mm SL. E. Detail of head of a specimen 52.0 mm TL. F. Detail of mid-body region of a 52.0 mm specimen. G. Leptocephalus, 59.0 mm TL. (*A, Original drawing, A. J. Lippson. B-D, Richardson, S. L., 1974: fig. 3. E-G, Fahay, M. P., and C. L. de Gorgue, MS.*)

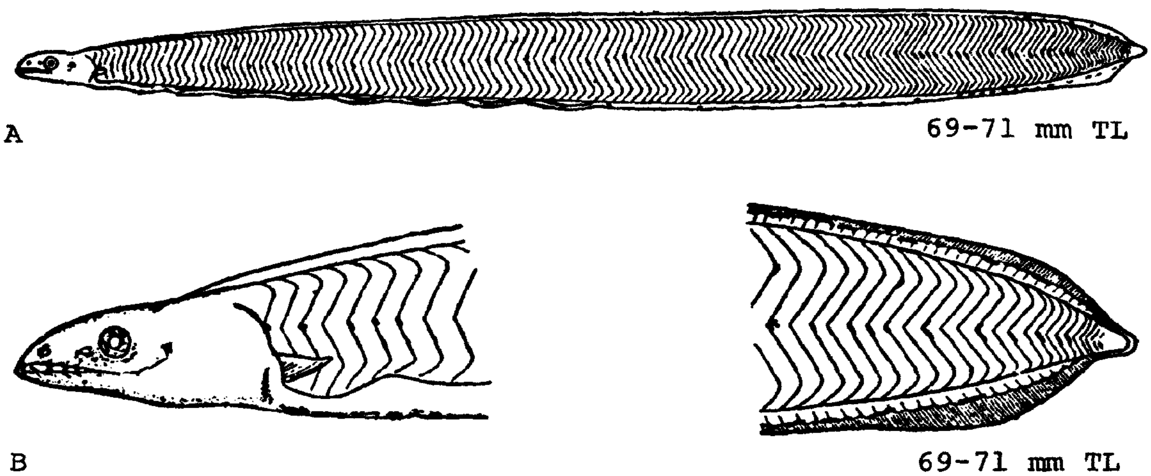

Fig. 28. *Pisoodonophis cruentifer,* Snake eel. A. Leptocephalus, 69–71 mm TL. B. Head and caudal region of A. (*A, B, Eigenmann, C. H., and C. H. Kennedy, 1901: fig. 11.*)

AGE AND SIZE AT MATURITY

No information.

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Scomberesox saurus

sauries
Scomberesocidae

FAMILY SCOMBERESOCIDAE

The family Scomberesocidae contains two genera and four species, one of which is undescribed. These fishes occur primarily in subtropical and temperate

Scomberesox saurus (Walbaum), Atlantic saury

ADULTS

D. 9–12 + 5–6 finlets; [12,49] A. 12–13 [10] + 5 [53]–7 finlets; [10] C. 3 + 14–15 + 4,[53] 12–13 branched rays; [22] P. 11 [53]–14; V. 6; [8,12] lateral scale rows 110 [13]–ca. 132,[57] predorsal scales 73–81; [26,70] total vertebrae 64 [6]–68; [68] preanal vertebrae 39–42; [6] gill rakers on first arch 5–6 [57] + 39–51; [68] branchiostegals 13.[53]

Proportions expressed as times in TL: Head 3.33–3.5, depth 9–13.[12,52,53]

Body elongate, compressed; [8] head long, broad above, narrow below, and tapering gradually to narrow beak; [33,53,60] lower jaw slightly longer than upper [8] (much longer in juveniles [42]); upper jaw thin, narrow.[53] Teeth minute,[28] in bands in jaw,[30] lacking on vomer, palatines, and tongue.[12] Scales small, deciduous.[8] Lateral line present, low on side.[10] Pelvics at mid-body; [23] dorsal and anal fin origins at about latter third of body (RLW), dorsal origin usually over fifth ray of anal.

Pigmentation: Variously described (and possibly varying with age and locality) as bright ultramarine blue,[53] dark blue,[9,12] greenish,[33] olive green,[10] olive brown,[13,60] or brownish above; [8] silvery white [9] or silvery with golden tinge below; a silvery lateral band as broad or nearly as broad as eye and almost at same level as eye; [8,60] lateral band with darker lower edge; [12] tip of jaw sometimes red, sometimes black; [18] a dark green or blue spot at pectoral base; [10,23] iris silvery [53] or silvery white.[57] Fins variously described: All fins dark brown,[41] "light" [49] or "pale"; [9] also upper fins dark, lower fins, including pectorals, yellowish,[12] dorsal greenish,[10,23] caudal and upper finlets grayish blue.[53]

Maximum length: Ca. 762 mm.[11,15]

DISTRIBUTION AND ECOLOGY

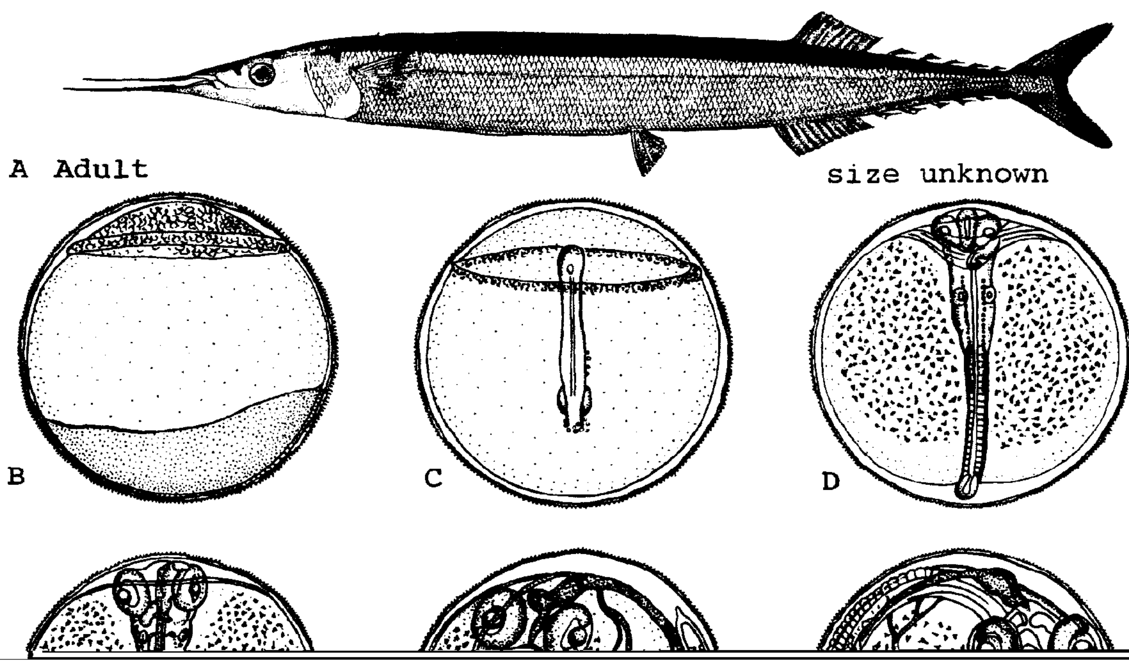
Range: *Scomberesox saurus* occurs in two widely separated disjunct populations: one in the North Atlantic (and possibly divided into two discrete populations) and the other in a circumglobal band in the southern seas (in both of these major areas, waters nearest the equator are used for reproduction and those nearest the poles are used for foraging). In the North Atlantic from the Canary Islands in the east to Norway and Denmark (and rarely the White and Barents Sea as far as Novaya Zemlya), then to Iceland and Nova Scotia, south along the North American coast to latitudes of Bermuda, also

parently north to at least 10° S in the central Atlantic. In the Indian Ocean from southeastern Africa (ca. 30° S) to northwestern part of Australia, also western and southern Australia, Tasmania, Victoria, and New South Wales. In the Central Pacific northward to 25° S latitude; in the eastern Pacific north to ca. 6° S on coast of Peru. Southern limit in all oceans between 45° and 50° S latitude, or roughly at the 10–12 C summer isotherm.[4,38,39,55,67,68,69,71]

Area distribution: New Jersey; [50] off Maryland; [32] mouth of Chesapeake Bay.[31,37,51]

Habitat and movements: Adults—a schooling, pelagic, or nektonic, migratory species [2,7,19,62,66] normally found in offshore waters at surface [8,15,54,56,58] but also recorded from bays, harbors, and the mouths of rivers. May ascend rivers to freshwater.[12,22,59] Frequently strand on beaches,[2] sometimes by thousands (as in Massachusetts); [8,25] stranding also reported in England,[5,27] Scotland,[24] Ireland,[21] and Norway.[17] Maximum depth, 30 m.[67] Salinity range, fresh [12] to full strength seawater.[7] Temperature range, 12 to 24 C (mostly at 15–19 C).[66]

Although Meek [35] suggested a general inshore-offshore movement in this species, with spawning taking place in mid-ocean, recent evidence suggests a typical north-south migratory pattern.[2,36,66,67] Sauskan and Semenov [67] state that, in the northwest Atlantic, *Scomberesox* moves northward in spring, arriving in New England from mid-June to October. Storer [29] and Bean,[61] however, report that it generally arrives in Massachusetts in fall, primarily in October. Nichols and Breder [15] found it "inshore" in New York and southern New England from August to December, although Leim and Scott [10] report it occurring in Canada only when the water is warmest. Off Maryland in August and September.[32] Zilanov and Bogdanov [66] comment that the northeast Atlantic population is generally restricted to the area below the 40th parallel during the winter, but moves northward to feed in spring and summer, reaching the 60th parallel in August and September. Saemundsson [36] found that populations in northern Europe retire in winter to warm waters around the Azores, Madeira, the west coast of the Iberian Peninsula, or "further south"; and in spring move in large shoals to the North Sea, Denmark, Norway, Sweden, the Faroes, and Iceland. (Individuals moving south through the North Sea in early autumn frequently strand, possibly as a result of low temperatures.) [2] Sauskan and Semenov [67] noted that in September and November, at the start of cooling, there is a northern



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northeasterly direction carried by waters flowing just

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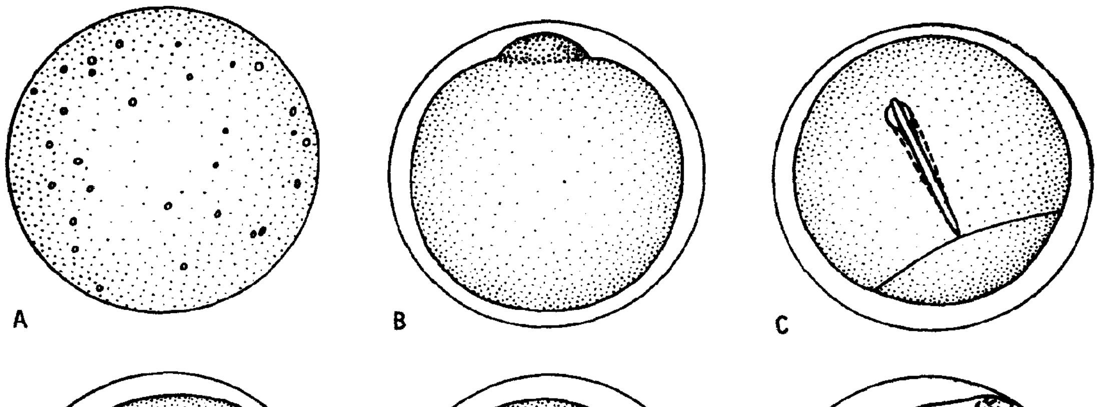
EGGS



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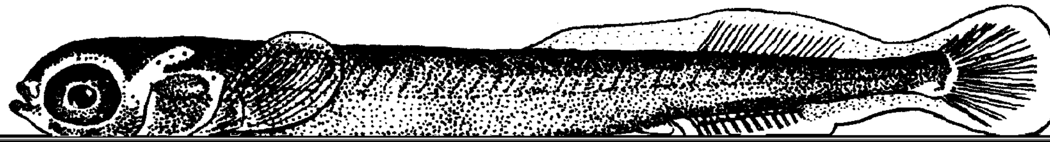
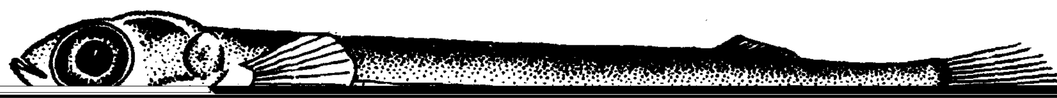
region of caudal fin a thickening of mesenchyme developed, rows of body pigment extended to end of body.

Tail overlapping head, prehatching embryo—Mouth opening noticeable, caudal rays forming, thickened mesenchyme developed in area of future anal, yolk mass noticeably decreased, eye pigmented.

Note: *There is apparently some geographic variation in pigment development. In saury from the North Atlantic pigment is evident on the head, body, and yolk when the embryo encompasses 1/3 of the yolk; in the same stage*

bottom of nasal fossa with fleshy stripe which ultimately divides nasal opening.[47] Dorsal finfold lost at 11.5 mm, preanal finfold at 14 [45]–ca. 25 mm.[46,47] Median fin ray formation variable: In one specimen, anal rays developing at 6.4 mm.[71] In 9.5 mm specimen, long incipient rays in dorsal, anal and caudal,[46,47] and in other individuals no median fin rays at 15–17 mm.[54] Caudal rounded, symmetrical at 9.5 mm, straight or slightly concave at 11.5–12.0 mm, definitely bilobed at ca. 20 mm.[45,47] Finlets first evident behind dorsal and anal at 15.0 [42]–18.0 mm.[56] Pectorals oblong or rounded at 9.5 mm,[46,47] at 11.5 mm relatively larger, more pointed than in earlier stages,[45]





[redacted]

B 21.5 mm TL

[redacted]


A
48 mm TL

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Ablennes hians
Strongylura marina
Tylosurus acus
Tylosurus crocodilus

needlefishes
Belonidae

FAMILY BELONIDAE

The family Belonidae occurs in tropical and temperate waters throughout the world. Members of the family are found in marine, estuarine, and freshwater, but are primarily surface-dwelling, schooling, marine and estuarine fishes. Needlefishes have slender, elongate bodies; fairly large, essentially opposite, posteriorly placed dorsal and anal fins; and relatively small pectoral and pelvic fins. Both jaws are conspicuously produced (except in two South American species in which the upper jaw is short), and are equipped with numerous sharp teeth. Most species are green or blue above with silvery lateral and ventral surfaces. Nine genera are currently recognized, and recent estimates of the numbers of species vary from 26 to approximately 60.

Needlefishes deposit large demersal eggs with well-developed chorionic filaments by which they are attached to plants or other objects in the water. Oil globules are absent in most species, but may be present as very tiny yolk inclusions in others. According to Breder (1959) eggs of *Strongylura notata* may be stranded and become semidesiccated. This may result in delayed hatching similar to that which occurs in the eggs of certain cyprinodontid fishes.

Ryder (1882) described the chorionic filaments of *Strongylura marina* eggs as being "looped and twisted together in all directions" and his illustration shows single filaments randomly distributed over the egg. Breder (1948) stated that the eggs "are provided with tufts of long threads." Foster (1974) described the chorion as having two discrete bunches of filaments at opposite poles of the egg. He concluded that the eggs described and figured by Ryder (1882) were those of *Tylosurus acus*, not *Strongylura marina*. In *Tylosurus acus*, however, the filaments are not single (as indicated in Ryder's figure) but are in discrete groups of two or three. Needlefish eggs reared at Chesapeake Biological Laboratory produced typical *Strongylura marina* larvae. These eggs, unfortunately, were not well described; however, unpublished sketches suggest that the filaments were single and randomly distributed as in Ryder's figure. Either some of the eggs used in the various descriptions were, in fact, misidentified, or the distribution of filaments on the egg of *Strongylura marina* is remarkably variable.

In larvae of the regional needlefishes the body is elongate and slightly tapered; the mouth is terminal; the anus is located roughly two-thirds the distance to the tip of the tail; there is a long preanal finfold; the dorsal and anal fins develop far back on the body; the urostyle is oblique at or near the time of hatching; and pigment is developed over the entire body even in the earliest stages, and not limited to discrete rows as in larval hemiramphids.

A conspicuous but transitory melanistic lobe develops in the posterior half of the dorsal fin in juveniles of *Tylosurus* and *Ablennes*. This structure never occurs in *Strongylura*. In *Tylosurus*, lappets appear on the lower jaw of developing juveniles, but these are lost in later development.

Key to belonid eggs of the Mid-Atlantic Bight.

1A. Eggs described 2
1B. Eggs undescribed .... *Ablennes hians*
2A. No oil globules in yolk 3
2B. Minute oil globules in yolk; chorionic filaments single, about equal to egg diameter; diameter 4.0–4.1 mm .... *Tylosurus crocodilus*
3A. Chorionic filaments in clusters of 2 or 3, conspicuously longer than diameter of egg; egg diameter 3.2–4.0 mm .... *Tylosurus acus*
3B. Chorionic filaments single, randomly distributed, generally less than diameter of egg; egg diameter 3.5–3.6 mm .... *Strongylura marina*

Key to yolk-sac larvae of Mid-Atlantic Bight belonid fishes.

1A. Yolk-sac larvae described 2
1B. Yolk-sac larvae undescribed .... *Ablennes hians*
2A. Pigment on dorsal and anal fins at ca. 10.0 mm 3
2B. No pigment on dorsal and anal fins at sizes less than 14.4 mm, 69–77 vertebrae .... *Strongylura marina*
3A. Pigment on body diffuse, melanophores widely separated; pigment developed only on dorsal and anal bases; in western Atlantic population, vertebrae 79–86 .... *Tylosurus crocodilus*
3B. Pigment on body dense, melanophores tending [illegible]

Ablennes hians (Valenciennes), Flat needlefish

ADULTS

D. 22 [51]–27 [9] (in western Atlantic 23–26); A. 24–29 (in western Atlantic 24–28); P. 13–15 [51] (a report of 12 [29] is questioned, JDH); V. 6; [4,46] vertebrae 82–97 (in western Atlantic 93–97); [51] scales along side to caudal base 410 [19]–ca. 520; [5] predorsal scales 360 [41]–430; [10] scales above lateral line 25.[10]

Proportions expressed as times in TL: Head 3.0–3.8, depth 15.9–16.5.[14] Proportions as percent of SL: Head width 2.6–3.5.[4]

Body very elongate, strongly compressed,[4,46] ribbon-like; [1] sides flattened,[29] nearly straight and vertical; [14] head compressed,[4] flattened on top, narrowly constricted below,[28] naked except on occiput and cheeks; top of head with broad, shallow, longitudinal groove; [36,43] preopercular bone porous.[51] Maxilla arched strongly upward; [15] jaws incapable of closing basally; [36,52] teeth in jaws rather small, in narrow bands, the inner ones enlarged, round, and sharply pointed.[14,43] Gill rakers and pseudobranchiae absent.[6,29] Scales minute,[11,35] narrowly imbricated.[36] Lateral line ventrad,[29] on edge of abdomen. Dorsal fin high, acutely falcate,[52] the anterior lobe notably elevated; [45] dorsal fin origin opposite anal fin origin; [48] caudal fin deeply forked; pectoral fin falcate; [16] base of pelvic fin nearer head than caudal fin.[48]

Pigmentation: Back brownish,[36,46] bluish,[46] or greenish [8,43] with bluish green reflections; [7,46] lower sides and abdomen bright silvery,[7,8] white,[46] or pearly,[19] with ventral pigment beginning abruptly.[52] Snout green [7,37] or tipped with red; [13] inside of mouth scarlet (Australian population); [51] iris silvery white.[41] A narrow dark green verte-

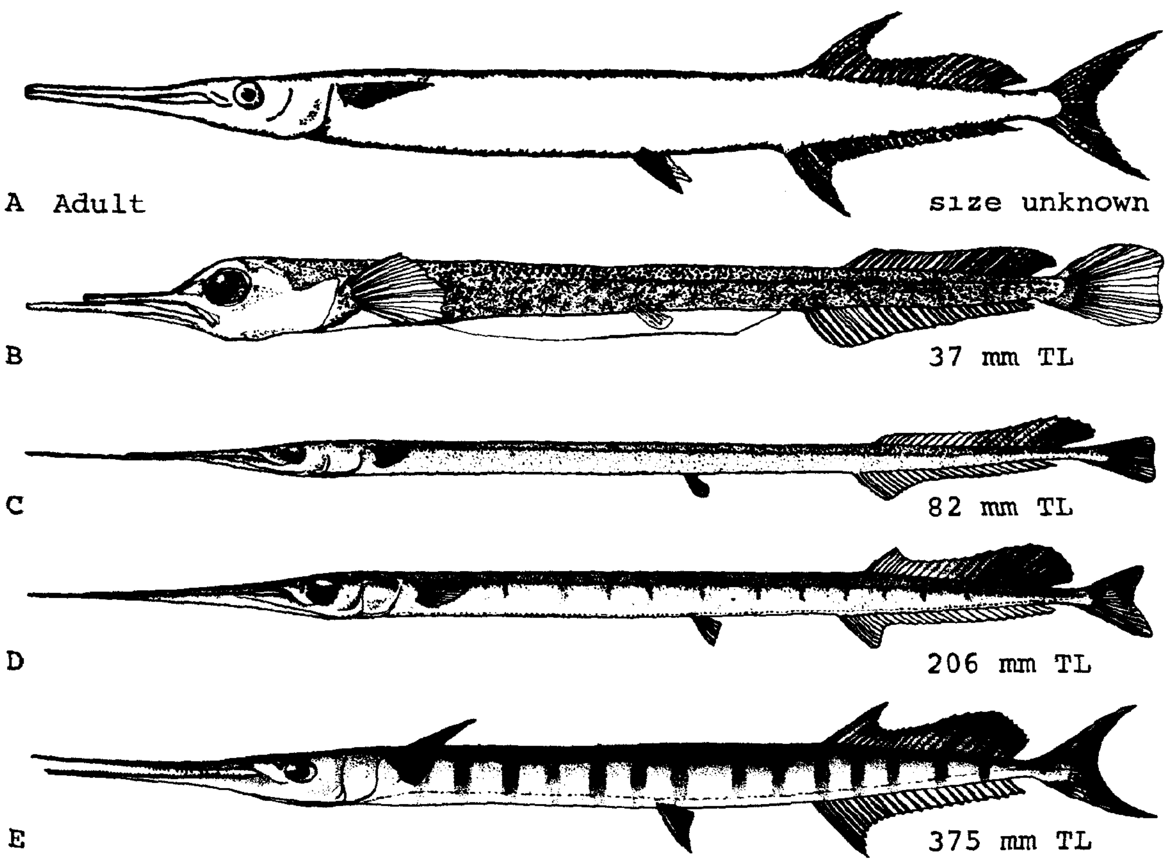


Fig. 35. *Ablennes hians,* Flat needlefish. A. Adult, size unknown. B. Larva, 37 mm TL. C. Juvenile, 82 mm TL. D. Juvenile, 206 mm TL. E. Juvenile, 375 mm TL. (*A, Bigelow, H. B., and W. C. Schroeder, 1953: fig. 80. B, Original drawing, Nancy S. Smith. C, D, Parin, N. V., 1963: fig. 17. E, Poll, M., 1953: fig. 68.*)

bral stripe from occiput to dorsal fin, below this a dark sea green band extending to tail.[46] Sometimes plain silvery,[14] otherwise marked with 3 [19]–15 black or blue-black quadrate bars of various sizes on sides, confined, at least in some specimens, to caudad section of body,[19,33,52] or with a pale bluish band along edge of dark color and on it 12 or more dark or dusky blotches; [41] sometimes with indistinct sooty or blue crossbars on back.[7] Dorsal fin described as greenish with rusty anterior edge,[46] with rays black-tipped,[7] or wholly black; [43] posterior lobe of dorsal fin melanistic throughout life; [51] anal fin yellowish [19] or dark greenish with rusty anterior edge; [46] caudal fin grayish [7] with upper and lower edges rusty red, or with tips nearly black; [43] pelvic fins yellowish,[19] or greenish black with rusty red anterior edge.[46] Also described as having all fins pale to dark brown.[36,37]

Maximum length: 1800 mm.[38]

DISTRIBUTION AND ECOLOGY

Range: Circumtropical; [32,49] both sides of the Atlantic Ocean,[9] throughout the Pacific Ocean [24,28] as far north as Japan, the Indian Ocean, and the Red Sea; [9] in the eastern Atlantic from Cape Verde Islands and Dakar through the Gulf of Guinea to the Congo and Moçamedes, southern Angola; [51] in the western Atlantic from Massachusetts [14,47] and Bermuda to San Salvador, Bahia, Brazil; widespread in the Gulf of Mexico.[3,20,45,53]

Area distribution: Coastal waters of New Jersey,[24,26,50] Delaware,[21] and Virginia; [8] north in Chesapeake Bay to vicinity of Potomac River.[13]

Habitat and movements: Adults—a pelagic species [38] found in water up to 3770 m deep; [42] also recorded inshore,[25,27,32] particularly at night; [34] maximum depth 17 m.[31] Apparently move northward or shoreward during summer in western North Atlantic, recorded from coastal waters of New Jersey in June and July.[26]

Larvae—no information.

Juveniles—a "quite young" specimen from Beaufort Harbor, North Carolina.[17]

SPAWNING

Location: Probably offshore.[4]

Season: Probably in spring (a specimen from North Carolina had ripe roe in May).[14]

Fecundity: No information.

EGGS

Ripe ovarian eggs. Diameter ca. 3.0 m.[14]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

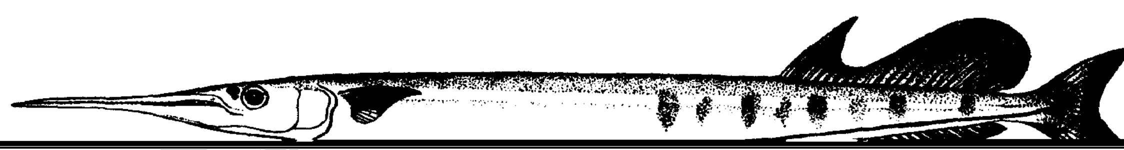
No information.

JUVENILES

Minimum size described: 37.0 mm TL (NSS).

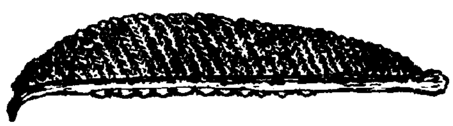
At 43.0 mm SL first gill arch with minute tubercles.[4] At 50.0 mm or slightly larger, tubercles of first gill no longer evident.[22] At 116–131 mm upper jaw short, lower jaw elongate.[39]

At ca. 56.5 mm SL upper jaw ca. 48 percent of lower jaw;



at 141–165 mm upper jaw 81–91 percent of lower jaw.[22] At ca. 123 mm depth in length to caudal ca. 24.[14] At 37.0 mm TL preanal finfold prominent (NSS). Posterior rays of dorsal longer than median ones [28] and forming a melanistic lobe which sloughs off with development [2] (the extended lobe still evident at 600 mm).[40] First pelvic ray usually branched at ca. 200–300 mm SL.[4]

Pigmentation: At 37 mm TL dorsum with numerous punctate melanophores, lower sides with widely spaced stellate melanophores, posterior part of dorsal fin dark (NSS). In young 12 [12]–15 dark, dusky, vertical or round blotches on sides; [18,30,35] posterior lobe of dorsal dark.[2] At 375 mm silver with iridescent specks, back slate gray, sides with 14–15 transverse vertical bars, especially visible toward back, fins grayish, ends of pectorals and posterior region of dorsal blackish.[38]



A

Fig. 37. *Ablennes hians,* Flat needlefish. A. First gill arch of a 52 mm SL specimen showing vestigial gill rakers. These are subsequently lost. (*A, Nichols, J. T., and C. M. Breder, Jr., 1928: fig. 169.*)

AGE AND SIZE AT MATURITY

No information.

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Strongylura marina (Walbaum), Atlantic needlefish

ADULTS

D. 14–17; A. 16–20;[72] C. 3+19+3;[19] P. 10[10]–13;[53] V. 6;[7,10] scales along lateral line ca. 300[4] to ca. 325,[24] predorsal scales 213–304, mean 255;[28,37] total vertebrae 69–77, precaudal vertebrae 41–50; caudal vertebrae 23–29.[72]

Proportions expressed as times in TL: Head 2.45–3.25, depth 14.3–20.0.[24] As times in SL: Head ca. 2.9. As times in head length: Depth ca. 5.5.[4]

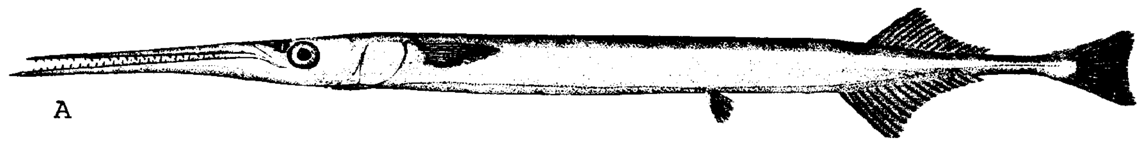
Body rather slender, cylindrical, not compressed;[17,24,52,68] a distinct caudal ridge or low keel on side of caudal peduncle;[4,20] jaws about twice as long as rest of head. Teeth in bands in jaws, sharply pointed, the innermost ones enlarged and canine-like.[24] Pelvics closer to anal than to pectorals;[4] caudal square or slightly concave.[23,24]

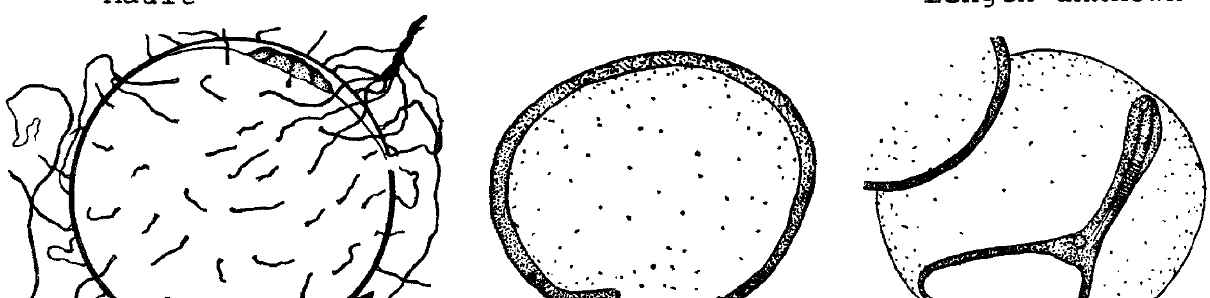
Pigmentation: Green above, silvery on sides, pale[4] or white[30] below; a silvery[7] or bluish silvery band on side becoming broader and less distinct toward tail;[13] snout dark green; cheeks and opercles silvery; a blackish vertical bar on upper part of opercle; scales and bones green;[20,24] pupil black.[21] Fins olivaceous;[30] dorsal somewhat dusky, longest rays yellowish at tips; caudal bluish at base, lobes yellowish; anal sometimes dusky.[24]

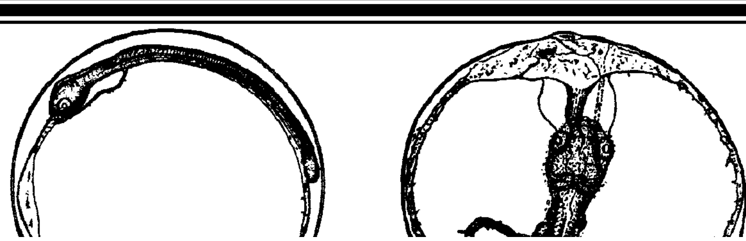
Maximum length: 1220 mm.[29,64]

DISTRIBUTION AND ECOLOGY

Range: Maine to mid-peninsular Florida; Gulf coast of United States and Mexico and southward, in coastal waters, at least to Rio de Janeiro, Brazil.[2] Records from







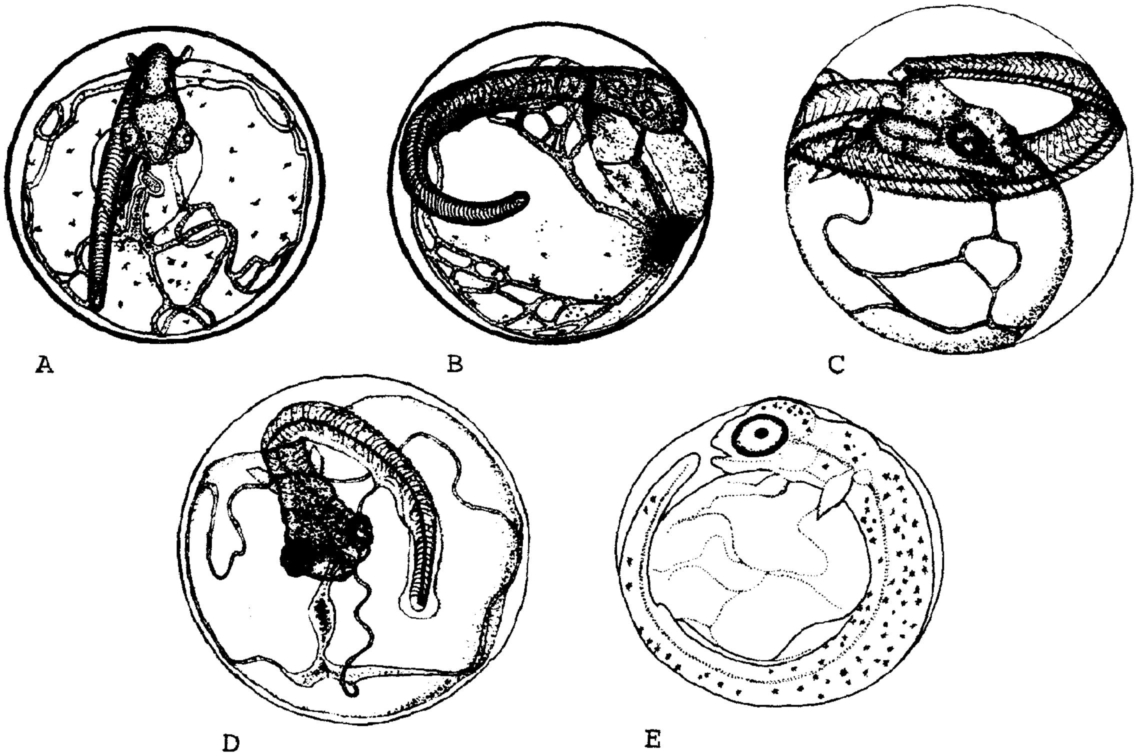


Fig. 39. ***Strongylura marina,*** Atlantic needlefish. A. Embryo, 116 hours and 40 minutes, pigment on yolk and heart, intestine and urinary bladder well-developed. B. Embryo, 165 1/2 hours, pericardial cavity enormously developed. C. Advanced embryo, age unknown, pigment developing on head. D. Advanced embryo, age unknown, finfold and pectoral fins developing. E. Embryo just before hatching, pigment well-developed on body. *(A-B, Ryder, J. A., 1882: pls. 19–21. C-E, Original drawings, Peni G. Lang.)*

the West Indies and Africa [8,15,39,41,63,66,69] refer to *S. timucu* and *S. senegalensis* (BBC).

Area distribution: Coastal waters of New Jersey,[5] Delaware,[55] Maryland,[1,24] and Virginia; [70] north in Chesapeake Bay to Havre de Grace, Maryland [24] and ascending regional rivers for considerable distances, i.e., to the vicinity of Washington, D.C., in the Potomac,[3,38] to Lancaster County, Pennsylvania in the Susquehanna,[57] and 64 km upstream in the Pamunky River, Virginia.[31]

Habitat and movements: Adults—primarily an inshore, shallow water species [10] usually found at the surface and ascending fresh water rivers at least 607 km to points up to 69.2 m above sea level; [14,25,40,56] also reported from lakes,[4] coastal ponds,[62] large springs,[32,58] and canals.[50] Landlocked populations may exist wholly within fresh water lakes in Florida.[18] Maximum salinity, 36.9 ppt.[18] Maximum temperature 32.9 C. Apparently make definite inshore-offshore movements according to the following observations: Inshore in Gulf coast bays in May and June; [65] in St. Johns River, Florida, April to October; [16] reported to run up the Potomac River "with the branch herring" and remain all summer; [3] arrives in upper Chesapeake Bay in April; [44] inshore in bays at Ocean City, Maryland from August to September 15; [46] May to mid-November in Long Island; [9] and in Hudson River and its tributaries in autumn.[7]

Larvae—yolk-sac larvae reported from freshwater feeders of the Delaware-Raritan Canal.[49]

Juveniles—specimens down to 22 mm along beaches in Long Island,[67] and specimens 25–50 mm long reported to form "solid green masses" in Long Island in October.[45] "Young" also in small creeks,[6] and a 23 mm specimen reported from Pamunky River, Virginia.[31] Specimens 125–245 mm long in lakes (connected to the sea),[46] rivers,[16] bays and harbors,[33,46] along beaches,[54] and in small groups around wharves.[43]

SPAWNING

Location: Inshore in bays and estuaries [10,22,24,29,30] (specifically recorded 12 to 27 m from shore in Florida bays); [60] possibly also in river mouths.[13] Freshwater spawning has been suggested in Florida; [36] yolk-sac larvae have been collected in fresh water feeders of the

Delaware-Raritan Canal;[27] and a running ripe female was collected 16 km above the tide in Chickohominy River, Virginia.[31] Maximum recorded salinity, 18.0 ppt.[51]

Season: Probably May and June in Rhode Island and New York, although large "immature" ovarian eggs have been observed in Rhode Island in August;[7,26] ripe adults from May 9[31] to August in Virginia;[12] gravid females as early as June 9 at head of Chesapeake Bay,[44] and with ovarian eggs of ca. 1.0 mm diameter on May 21 in bay;[24] near ripe females in mid-February in Texas,[42] and spawning from April 25 through June in Florida and the Gulf of Mexico[38,60] (records from the Gulf coast may be based in part or in whole on *Strongylura timucu*[2]).

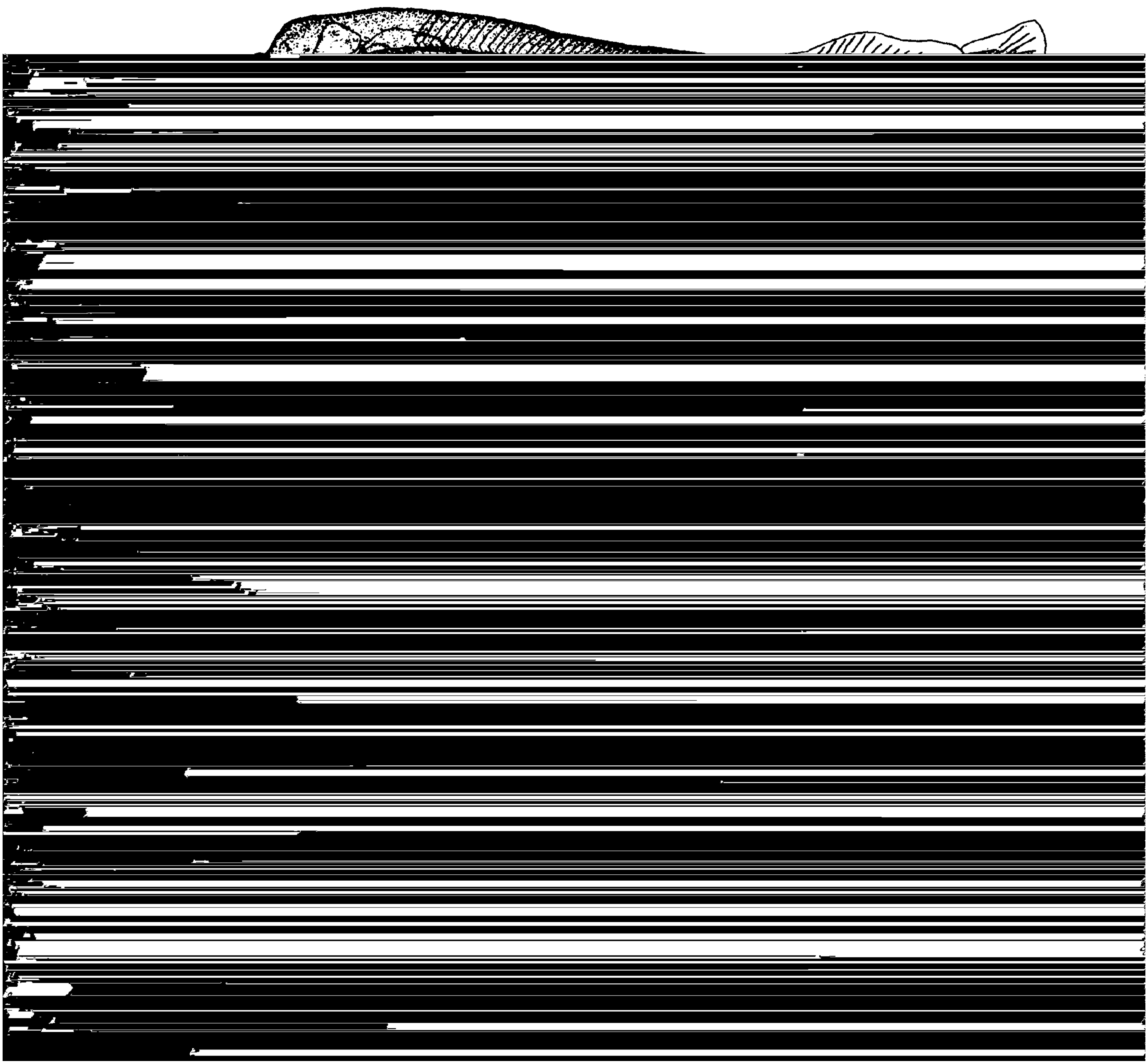
Fecundity: Unknown.

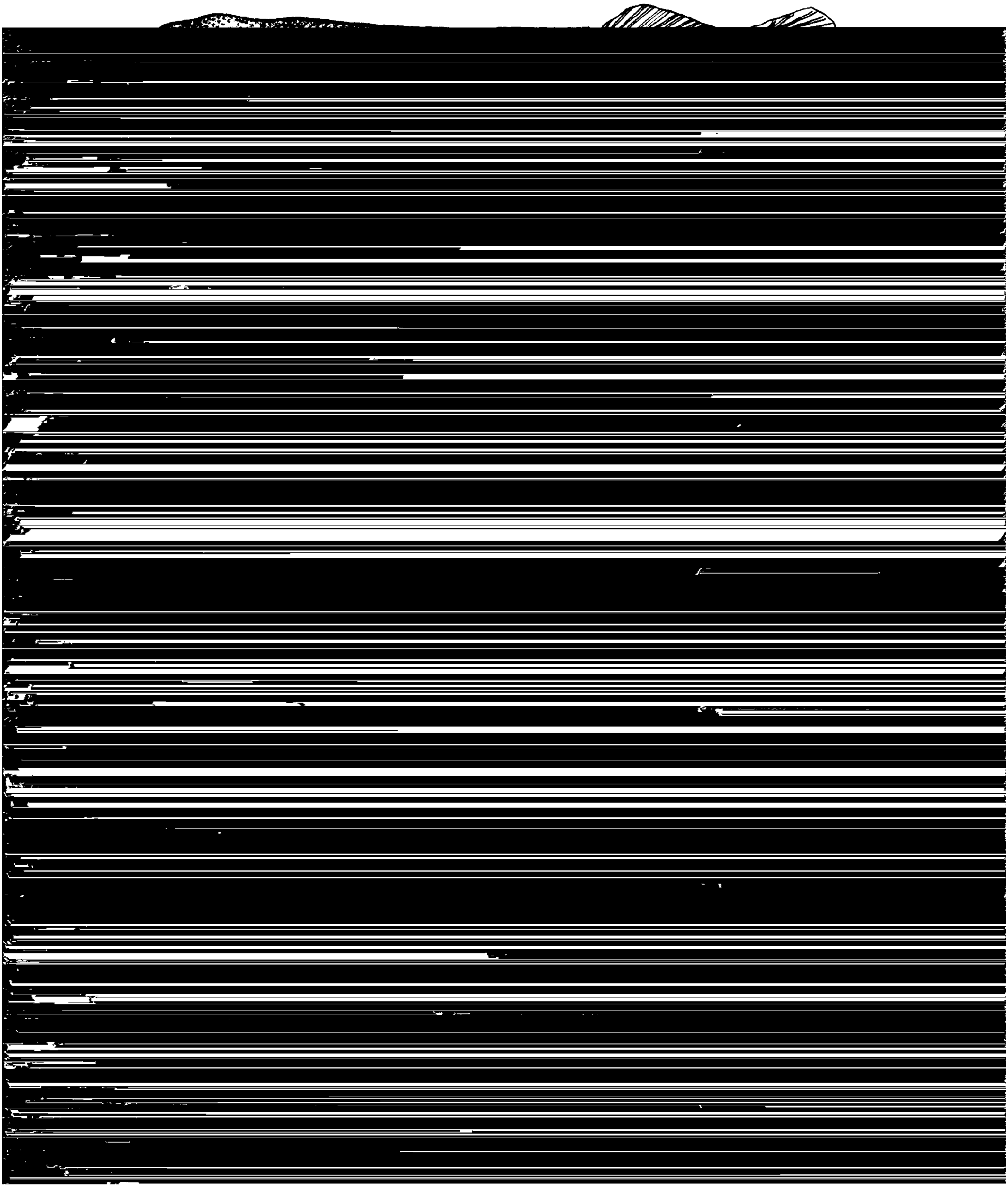
EGGS

Description: Demersal,[12] attached to weeds and other objects and remaining in compact masses.[11,61]

Ovarian eggs: Egg membrane with tightly coiled filaments even in ovarian follicles.[12,61]

Fertilized eggs: Diameter ca. 3.5–3.6 mm;[12,61] entire egg,





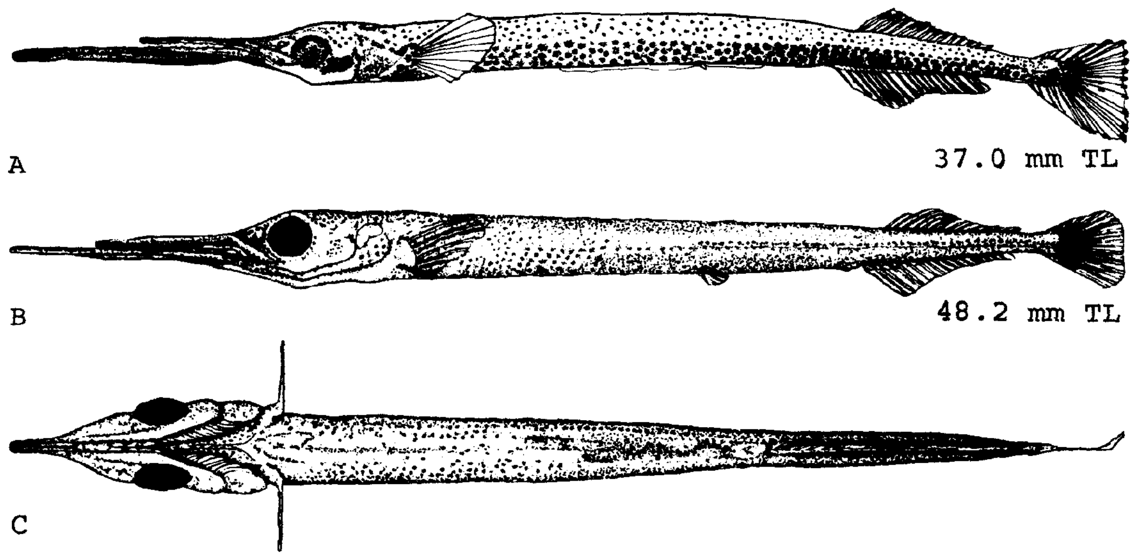


Fig. 42. *Strongylura marina,* Atlantic needlefish. A. Larva, 37.0 mm TL. B. Larva, 48.2 mm TL. C. Ventral view of B. (*A, Original illustration, Nancy S. Smith. B, C, Original illustrations, Peni G. Lang.*)

Finfold small except preanally, continuous between dorsal and caudal and anal and caudal, but not developed in front of dorsal. Incipient rays in dorsal, caudal, and anal throughout stage. Urostyle flexed at hatching (PGL).

Pigmentation: Pigment developed dorsally above lateral line, on yolk sac, and in eye throughout stage (PGL). In a 14.4 mm TL specimen, a distinct broad band of pigment on lateral aspect of body between head and anus.[73]

LARVAE

Size range described 25.3–48.2 mm TL.

Jaws equal in length at beginning of stage, lower jaw much longer than upper by end of stage. Preanal finfold evident to 37.0 mm. Pelvic buds developed at 30.0 mm (PGL).

Pigmentation: At 25.3 mm melanophores scattered over head and body, large melanophores concentrated on lower sides anterior to anus, and a distinct row of melanophores on each side of mid-dorsal line. At 30.0–37.0 mm body and head covered with large melanophores, these concentrated on body below lateral line. At 48.2 mm melanophores more numerous, punctate (PGL).

JUVENILES

Minimum length described, ca. 45.0 mm.[47]

At ca. 45.0 mm caudal peduncle relatively deeper than in adult, eye relatively larger.[47] At 44.5 mm SL upper jaw ca. 60 percent of lower jaw, at 114–129 mm SL, ca. 85–89 percent of lower jaw.[34] At 170 mm SL jaws approximately equal.[9] At 200–300 mm SL (thus possibly including adults) first ray of pelvic fin branched.[10] Caudal fin somewhat forked at ca. 45 mm.[22]

Pigmentation: At ca. 45 mm, dark above, light below; a definite dark mid-lateral band of pigment from eye to base of caudal becoming progressively lighter and more narrow posteriorly.[22]

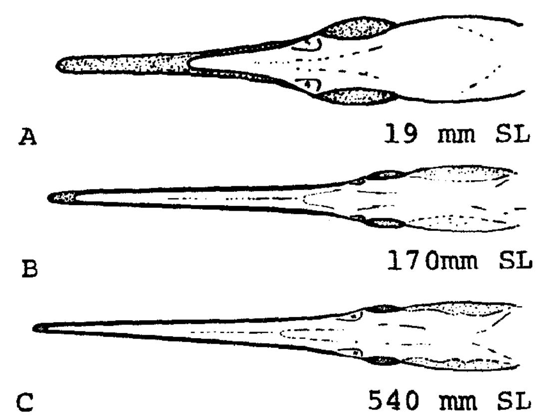
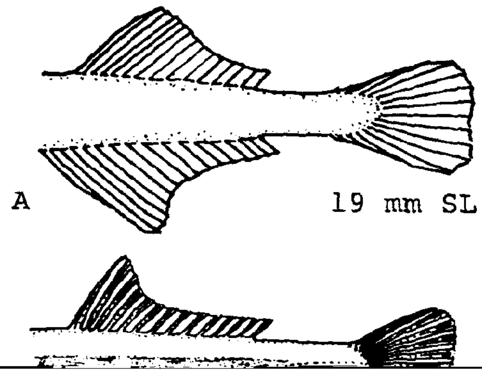


Fig. 43. *Strongylura marina,* Atlantic needlefish. A-C. Development of head and beak. A. 19 mm SL. B. 170 mm SL. C. 540 mm SL. (*A-C, Breder, C. M., Jr., 1934: pl. 1.*)

AGE AND SIZE AT MATURITY

Age at maturity, possibly during 2nd season; minimum size at maturity, ripe ovaries in a specimen not much greater than ca. 205 mm.[22]



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Tylosurus acus (Lacépède), Agujon

ADULTS

D. 20–27 (in western Atlantic 22–26); A. 18 [41]–25 [22] (in western Atlantic 20–24 [41]); C. 14 [22]–16; P. 12 [24]–14; [7] V. 6; [7,24] vertebrae 74–96 (in western Atlantic 90–95), vertebral count also given as 55 + 28 (based on specimen from Java Sea); [32] scales in lateral series ca. 350 [5]–400,[11,12] predorsal scales 267–430 (325–389 in western Atlantic); [41] branchiostegals 14.[22,25]

Proportions expressed as times in TL: Head 2.6, depth 18.5 [11]–22.0.[25,30] Proportions as percent SL: Lower jaw 22.4–23.8 (in specimens larger than ca. 170 mm), lower jaw extension 1.6–3.7, length of anal lobe 5.5–6.2.[7]

Body elongate, slightly compressed, a little deeper than broad; caudal peduncle depressed, broader than deep, and with lateral keel; head somewhat depressed above; cheek and opercle straight, nearly vertical; [4,11] preopercle scaled, opercle naked; [11] eye ellipsoid.[28] Teeth in bands in jaws, the inner ones enlarged, pointed; longest teeth near center of length of snout.[11,25] Scales small, cycloid; lateral line complete, upturned on caudal peduncle.[11] Dorsal and anal fins opposite, but last anal ray considerably anterior to last ray of dorsal; dorsal and anal fins both with enlarged anterior lobes.[14,25]

Pigmentation: Dark green,[4,28] dark blue with greenish flashes,[25] brilliant ocean blue, or brownish above; [12] sil- [redacted]

species, although frequently recorded inshore,[7,16] particularly in inlets,[6] harbors,[21] and shallow bays,[31] also at breakwaters.[38] Minimum salinity, 28.7 ppt. May move inshore during late summer and fall; thus recorded from Beaufort Harbor, North Carolina in June,[3] early July,[21] September, October and November.[3]

Larvae—no information.

Juveniles—specimens 114 mm long recorded from harbors; [14] "young" may follow floating offshore weeds.[18]

SPAWNING

Location: Probably offshore waters.[7]

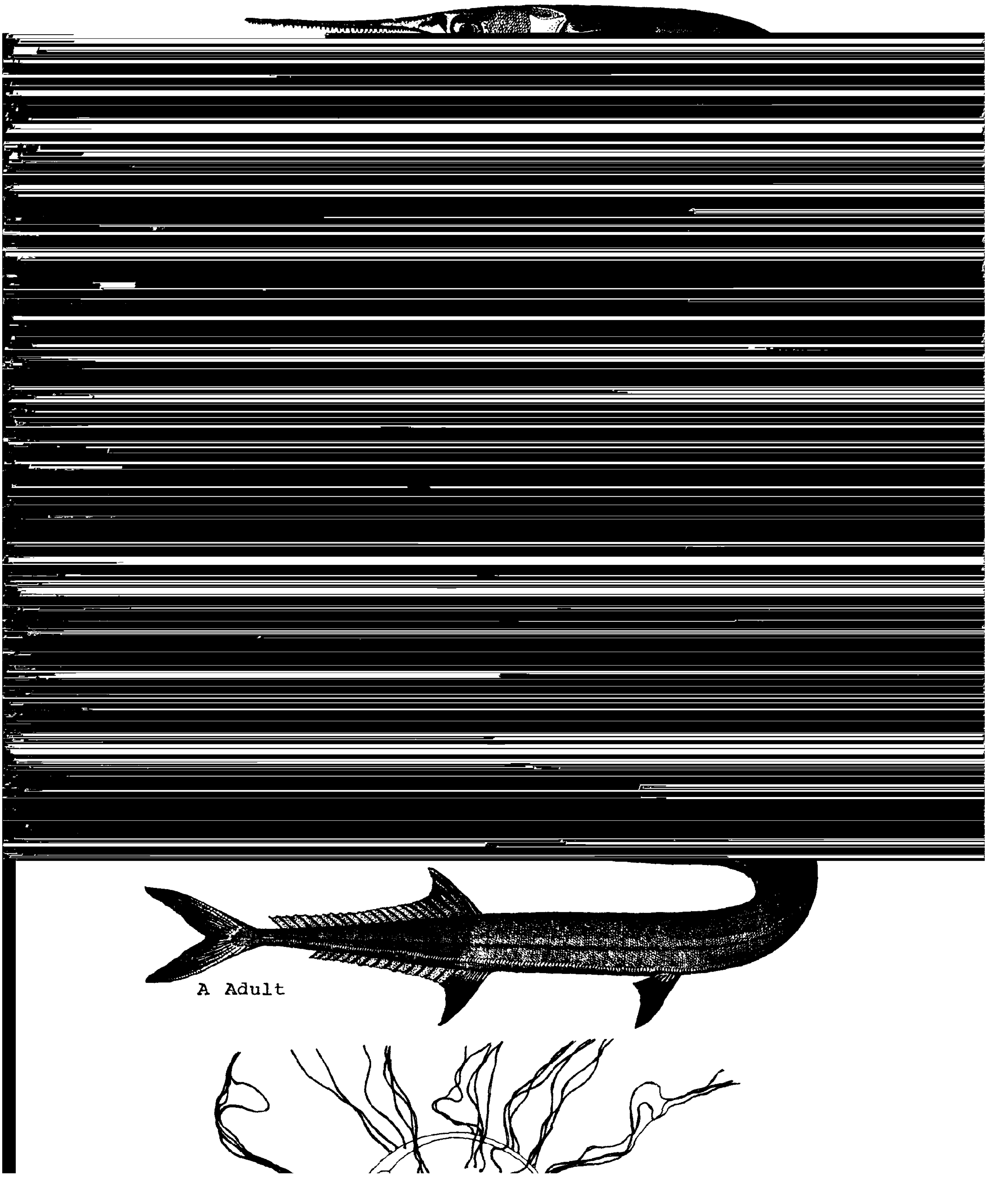
Season: Spring in the Bahamas and West Indies; [17] March to May in Haiti; June through July at Dry Tortugas, Florida.[5,12]

Fecundity: No information.

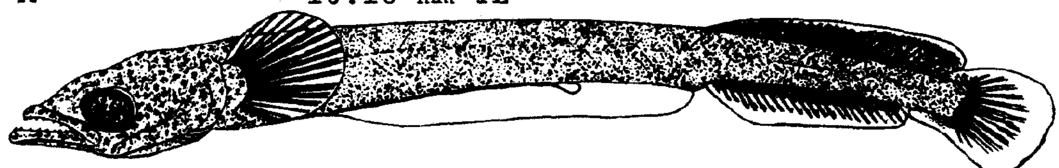
EGGS

Location: Demersal, presumably entangled together and attached to objects in the water.[34]

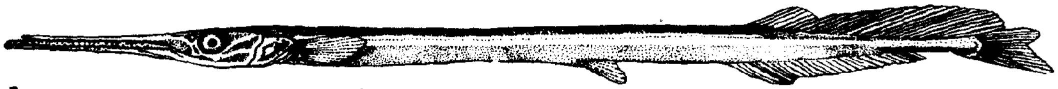
Fertilized eggs: Diameter 3.22 [34]–4.0; egg membrane with long attachment filaments; [32] filaments apparently longer [redacted]


A Adult

A 10.16 mm TL



B 14.10 mm TL



A 192 mm TL

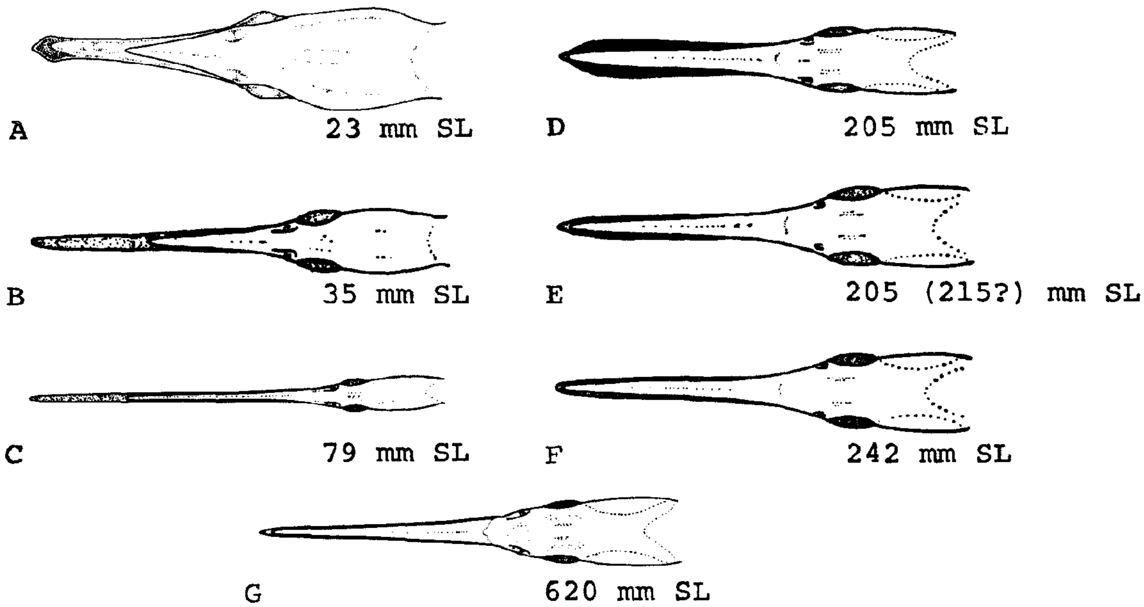


Fig. 48. *Tylosurus acus*, Agujon. Development of head and beak. A. 23 mm SL. B. 35 mm SL. C. 79 mm SL. D. 205 mm SL. E. 205 (or 215) mm SL. F. 242 mm SL. G. 620 mm SL. (*A, Breder, C. M., Jr., 1934: pl. 2, Elizabeth Ray Peters, delineator. B, C, G, Breder, C. M., Jr., 1934: pl. 2. D, E, F, Breder, C. M., Jr., and P. Rasquin, 1954: fig. 1, fig. E reported as 215 mm in fig. 7 of source.*)

Pigmentation: Young up to ca. 30 mm sometimes light green with four broad bands of bright silver, the first through the eye, the second just in advance of the pelvics, the third at dorsal origin, and the fourth at caudal peduncle. In young pectorals usually hyaline or dusky.[12] In a specimen ca. 115 mm long posterior lobe of dorsal black [5,12] and black pigment also on caudal fin.[14] At ca. 150 mm bright silvery, translucent, somewhat darker above, and with indistinct dark bars on side.[18] A juvenile of unknown size, but with dorsal lobe black, was dark blue above, pale grayish tinged with red on sides, grayish below, and with fins yellowish and dusky.[27]

AGE AND SIZE AT MATURITY

First mature in 2nd or 3rd year; [12] or at ca. 600–700 mm SL.[5,12,15]

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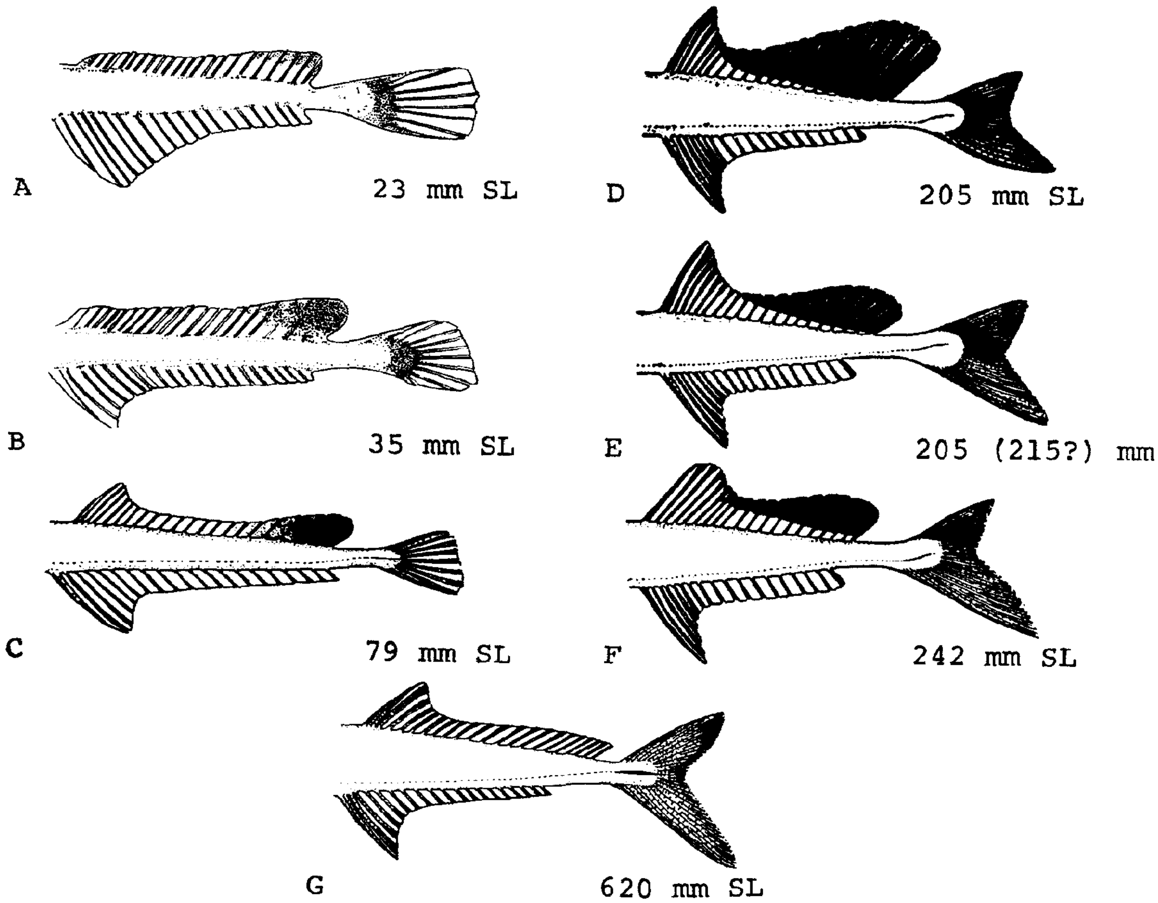

Fig. 49. *Tylosurus acus*, Agujon. Development of median fins. A. 23 mm SL. B. 35 mm SL. C. 79 mm SL. D. 205 mm SL. E. 205 (or 215) mm SL. F. 242 mm SL. G. 620 mm SL. (*A, B, Breder, C. M., Jr., 1934: pl. 5, Elizabeth Ray Peters, delineator. C, G, Breder, C. M., Jr., 1934: pl. 5. D-F, Breder, C. M., Jr., and P. Rasquin, 1954: fig. 2.*)

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Tylosurus crocodilus (Peron and Lesueur), Houndfish

ADULTS

D. 18–25 (in western Atlantic 21–23); A. 17–22 (in western Atlantic 18–22);[65] C. 28;[14] P. 14–15; V. 6;[27,56] vertebrae 67–86 (in western Atlantic 79–86),[65] preanal vertebrae 55[27]–57, caudal vertebrae 27[29]–28;[27] scales in lateral series 195[46]–388,[54] scales between occiput and dorsal fin 138–142;[46] teeth on each side of upper jaw ca. 25, on each side of lower jaw 23.[2]

Proportions expressed as percent SL (includes juvenile): Head width 5.0–6.0 in specimens longer than 100 mm SL; head depth 5.5–6.8 in specimens longer than 60 mm SL; lower jaw length 18.8–21.8 in specimens larger than ca. 170 mm; anal length 7.2–9.5.[7] Beak ca. 1 1/2–1 5/6 times in rest of head;[18] greatest width of body 1.1–1.3 times in greatest depth.[56]

Body robust, elongate, slightly compressed;[2,26,58] caudal peduncle cylindrical, about as wide as deep;[54] caudal keel rather strong;[15] head flat above, somewhat quadrate, a little deeper than wide, middle of upper surface with very shallow groove.[18] Scales minute;[10] opercle naked[43,52] or with scales on anterior margin.[55] Lateral line with short branch to pectoral base.[54] A broad band of small outer teeth and an inner row of large, strong, canine-like teeth in both jaws; vomerine teeth lacking;[22,54,58,63] gill rakers absent.[23] Dorsal fin exactly or nearly opposite anal;[8,10] caudal fin deeply forked,[22] the lower lobe much [illegible]

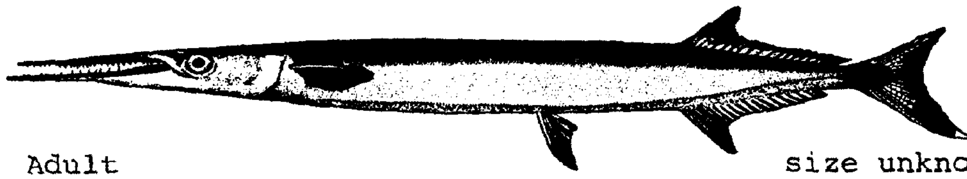
Japan;[44,50] in eastern Pacific, Cape San Lucas and Mazatlán, Mexico, to Galapagos Island.[20]

Area distribution: Coastal waters of Maryland[20] and New Jersey;[35] also off Lewes, Delaware.[20]

Habitat and movements: Adults—a pelagic[45] schooling species[37] (although largest fish may, at least at times, travel singly or in pairs[4]) found both offshore in open sea (where possibly more abundant[7,9]) and to within 9 m of shore;[32] recorded from shallow bays,[38] lagoons,[30,56] harbors,[32] and coral reefs[37,41,59] in both open water along rocky shores and over beds of turtle grass,[32] also from mangrove channels (FDM); typically at surface at night,[45] with larger fish sometimes in large schools. Move inshore at night,[4] and apparently tend to remain inshore during spawning season.[76]

Larvae—yolk-sac larvae initially move on substrate by lateral flickering of tail, subsequently swim upward; remain motionless at surface.[64]

Juveniles—specimens 21 mm long remain at surface;[64] at 30–50 mm at surface up to 1.6 km or more offshore;[17] at ca. 50–150 mm associated with drifting flotsam such as broken eelgrass and weeds,[4,11,21,29] and reported to float head down in these circumstances[31] (association with flotsam is abandoned before loss of early juvenile traits, i.e., expanded dorsal lobe and mandibular lappets[19]); at 200–250 mm form small schools along shore



A Adult size unknown

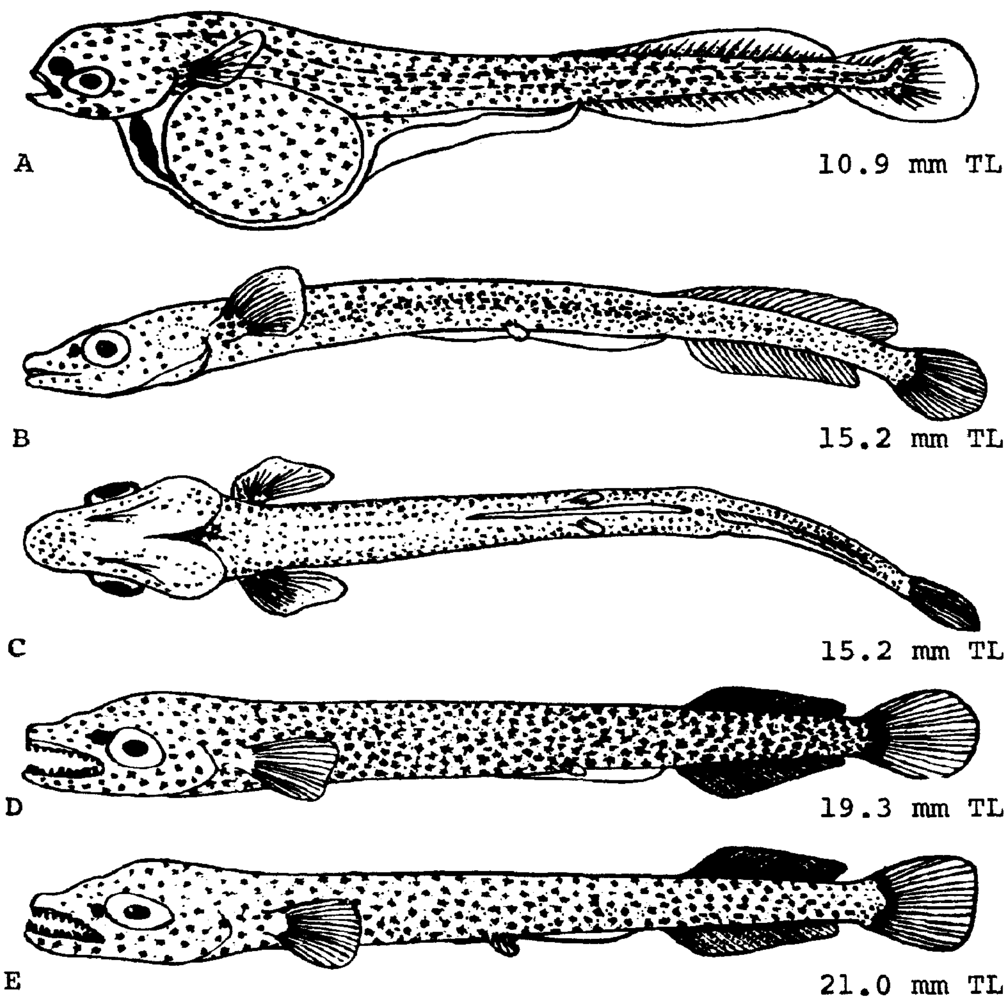


Fig. 51. *Tylosurus crocodilus*, Houndfish. A. Yolk-sac larva, 10.9 mm TL, newly hatched. B. Larva, 15.2 mm TL. C. Ventral view of B. D. Larva, 19.3 mm TL. E. Juvenile, 21.0 mm TL. (*A-E, Masurekar, V. B., 1967: figs. 3–7.*)

Optimum rearing temperature: 28–29 C.[64]

Optimum pH: 7.9–8.1 (high mortality was observed at pH 7.5).[64]

YOLK-SAC LARVAE

Hatching length, 10.7–12.0 mm. Specimen described, 10.9 mm.[64]

Duration of stage, ca. 24 hours (yolk sac more or less completely absorbed).[64]

At 10.9 mm, head free from yolk; yolk sac broadly oval; upper jaw oblique; lower jaw slightly longer than upper; dorsal finfold to slightly beyond level of anus; preanal finfold wide; urostyle oblique; incipient rays in dorsal (ca. 20), anal (ca. 19), caudal (ca. 15), and pectorals.[64]

Pigmentation: At 10.9 mm head and body more or less uniformly covered with brownish black melanophores and orange chromatophores; body gray in appearance when viewed from a distance; basal portions of median fins uniformly scattered with black melanophores; dorsal and caudal tinged with orange.[64]

LARVAE

Size range of specimens described, 12.9–19.3 mm. Duration of stage 24 hours to 6 days (2 specimens are described without known size: one 36 hours old and one 44 hours old.[64] These are probably between 12.9 and 15.2 mm long, JDH).

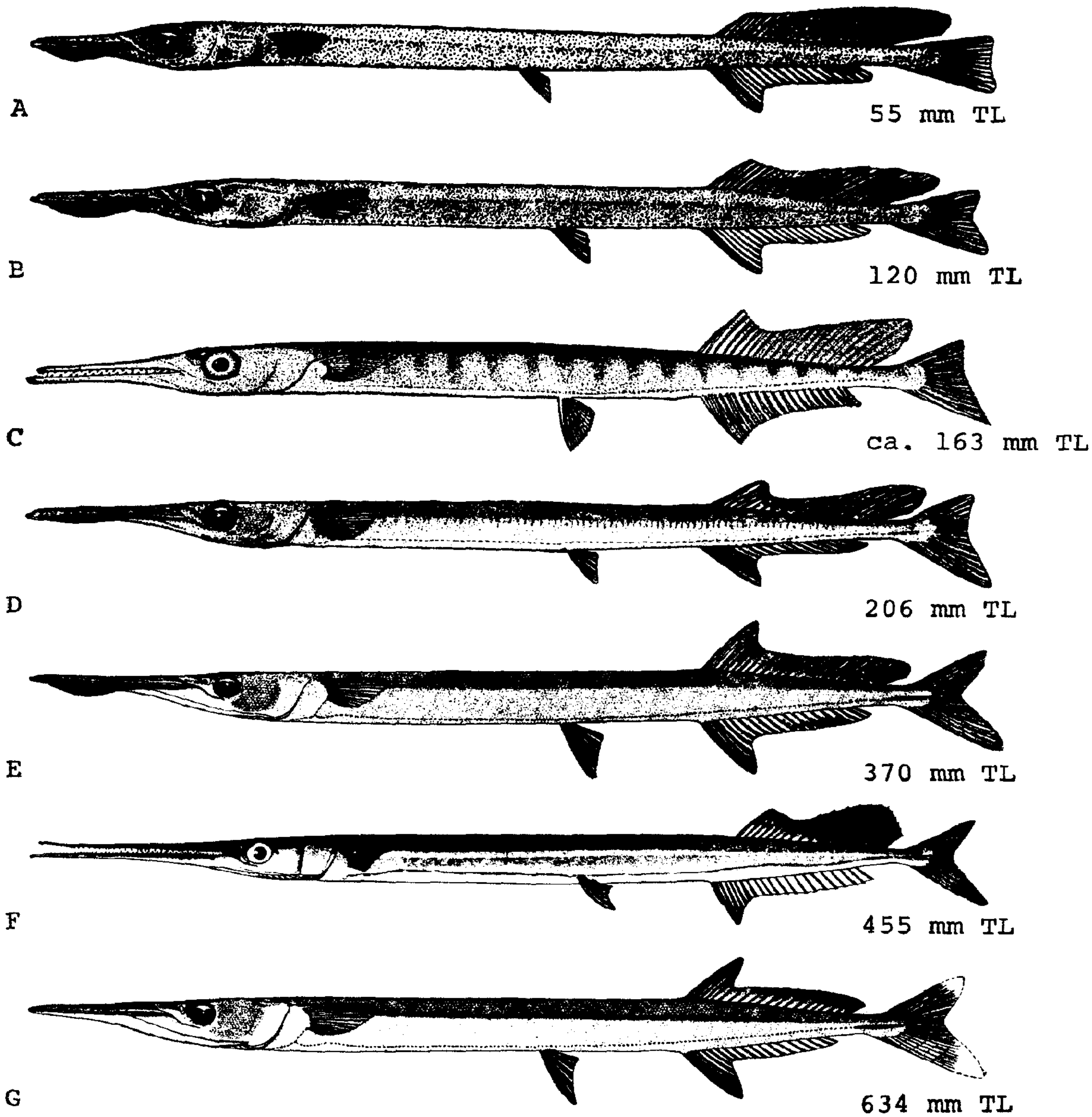


Fig. 52. *Tylosurus crocodilus*, Houndfish. A. Juvenile, 55 mm TL. B. Juvenile, 120 mm TL. C. Juvenile, ca. 163 mm TL. D. Juvenile, 206 mm TL. E. Juvenile, 370 mm TL. F. Juvenile, 455 mm TL. G. Possible juvenile, 634 mm TL. (*A, B, D, E, G, Parin, N. V., 1967: fig. 22. C, Bean, T. H., 1903: fig. 15. F, Poll, M., 1953: fig. 38.*)

At 15.2 mm body elongate, cylindrical; at 19.3 mm head and anterior half of body comparatively deeper.[64] At 11 mm SL scarcely any beak at all, lower jaw decidedly prognathous; [4] at 44 hours jaws slightly elongate. Minute teeth at 44 hours; teeth conspicuous at 19.3 mm. Eye noticeably oval at 19.3 mm; nostrils distinct at 12.9 mm. Pelvic buds evident at 36 hours, all other fins with full ray complements at 12.9 mm; caudal truncate at 19.0 mm.[64]

Pigmentation: At 12.9 mm tip of snout to region of pectorals greenish yellow; dorsal and dorsolateral region behind pectorals with small stellate black melanophores giving gray appearance to region; melanophores along ventral and ventrolateral surfaces larger, more conspicuous; top of head, behind eyes, crowded with black stellate melanophores. At 36 hours whole body greenish yellow or brown; head with mixture of black stellate melanophores and orange spots; dorsal finfold completely black; belly less pigmented than rest of body. At 15.2 mm pigment heavily concentrated along sides; chromatophores at base of pectorals more conspicuous; 3–4 large chromatophores in row along isthmus; pelvics unpigmented. At 19.3 mm ventrolateral region with pitch black melanophores; melanophores of rest of body faint brownish; interspinous membrane of dorsal and anal deeply pigmented; caudal fin deeply pigmented at base, otherwise colorless; pelvics and distal parts of pectorals colorless.[64]

JUVENILES

Minimum size described, 21.0 mm.[64]

Head measured from tip of upper jaw 3 times in TL in young; depth 7.2 times in distance from occiput to dorsal.[54]

At 24–50 mm jaws short, strong; [34] no pronounced half-beak condition at any time, jaws nearly co-terminal at all sizes.[4,18] Beak of "young" more slender and proportionately longer than in adult.[13] At 21 mm 11 teeth on each side of upper jaw, 9 on each side of lower, the upper series the strongest; teeth well-developed, raptorial at 30 mm,[4,17] distinctly curved forward in specimens less than 500–600 mm long.[12,65] A thin, flexible, membranous flap capable of muscular movements developed on each side of lower jaw, beginning at 19.5 mm and retained to sizes of less than ca. 150 mm SL [4] to extreme of 300 mm SL; [19] at 165 mm flap folded under lower jaw, meeting its fellow from the opposite side.[2,3] Second lobe of dorsal fin greatly extended and darkly pigmented; time of formation of lobe variable, just beginning to elongate in some specimens at 11 mm SL, and not evident, or well-developed, in others at 59 mm; [4,19] at maximum development (ca. 150 [18]–165 mm) lobe heavily pigmented and capable of moving in water like flag; [4,19] longest dorsal ray equal to distance from middle of pupil to end of head; [2] elevated lobe retained in some specimens to 300 mm SL; [19] lost through disintegration or sloughing rather than resorption,[18] the loss accompanied by elevation of anterior dorsal rays which soon exceed length of posterior rays. Last anal rays not elevated [4] (a report of last anal rays much elevated [55] is questioned, JDH). First pelvic ray branched at 200–300 mm SL.[7] Caudal definitely forked in some specimens at 19.5 mm SL,[4] apparently rounded in others at 30–50 mm.[17] Preanal finfold still evident at 21 mm.[64] Lower jaw extension 0.5–1.6 percent of SL in specimens smaller than ca. 170 mm SL.[7]

Pigmentation: At 21 mm faint brownish stellate chromatophores on upper body, ventral and ventrolateral surfaces dark.[64] At 25–50 mm posterior rays of dorsal blackish, other fins whitish.[34] Specimens up to about 50 mm capable of extensive and rapid color changes, apparently matching environment in shade and, to some

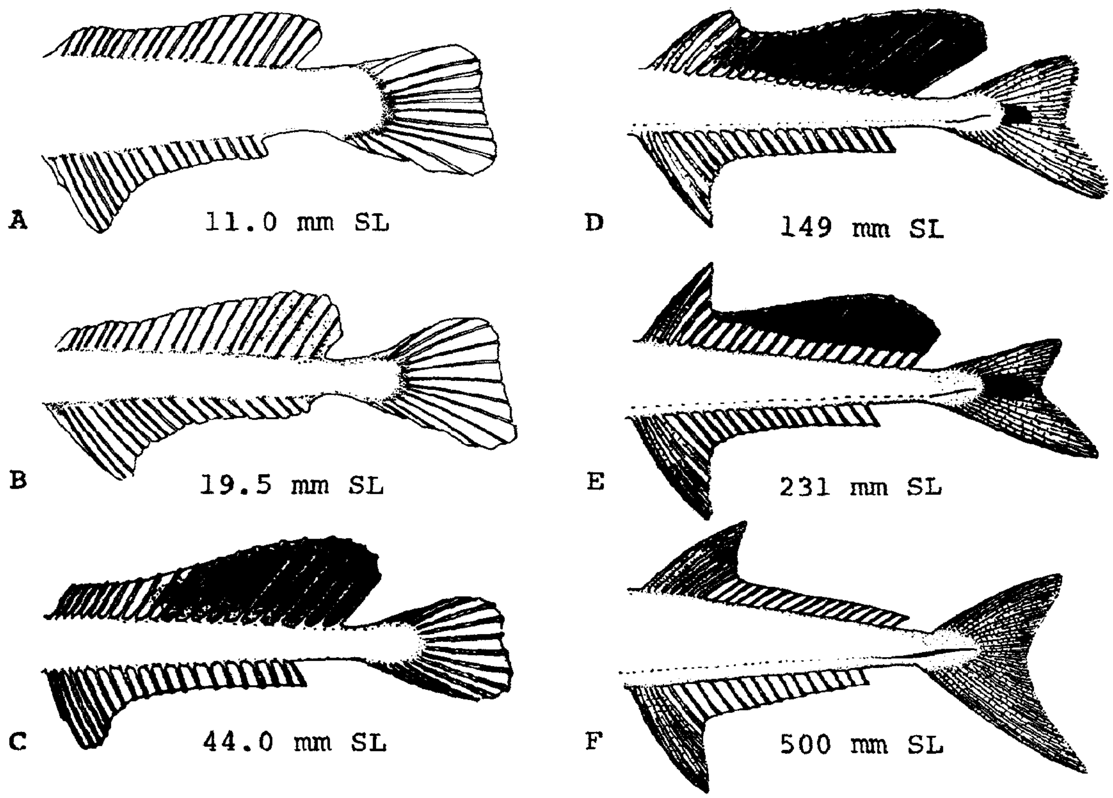


Fig. 54. *Tylosurus crocodilus*, Houndfish. Development of dorsal fin. A. 11.0 mm SL. B. 19.5 mm SL, pigment developing on posterior lobe of dorsal. C. 44.0 mm SL. D. 149 mm SL, posterior lobe of dorsal at maximum development. E. 231 mm SL, dorsal lobe diminishing. F. 500 mm SL, definitive form of dorsal fin established. (*A, B, Breder, C. M., Jr., 1934: pl. 4, Elizabeth Ray Peters, delineator. C-F, Breder, C. M., Jr., 1934: pl. 4.*)

extent, pattern, commonly pale cream to tan; some individuals of these sizes with dark band and resembling *Sphyraena barracuda*.[4,24] At 50 mm light brown above, brownish below, lappets jet black.[17] At 59 mm back olive-green, prominently sprinkled with melanophores; color of back bounded by black lateral stripe from snout to top of central caudal rays; silvery below, except for dark band running from isthmus to vent; lower jaw black below; lateral band about 3/4 diameter of eye; ventral band 1/2 eye diameter; iris golden centrally, silvery below, brownish above; fins hyaline.[4,5] A specimen ca. 114 mm long from Bermuda was apparently patternless, but was covered throughout with stellate chromatophores.[6] At ca. 152 mm straw-colored, possibly to match flotsam in environment;[21] adult pattern may develop at this size. At ca. 165 mm greenish above; silvery below; 14 black

30 mm, jet black at 50 mm.[17] In "young" an overall reddish cast and conspicuous black bars while black dorsal lobe is evident;[31] lateral pattern also described as a row of large, round, dusky spots;[33] final shape of dorsal fin foreshadowed by shape of melanin area before 2nd dorsal lobe is lost.[19]

AGE AND SIZE AT MATURITY

Mature at 1 1/2 years[19] to possibly 3rd year,[18] and 446[10]–800 mm.[4]

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Cheilopogon heterurus

flyingfishes
Exocoetidae

FAMILY EXOCOETIDAE

Flyingfishes are closely related to the halfbeaks (Hemiramphidae) and the flying halfbeaks (Oxyporhamphidae). Although Greenwood, *et al.* (1966), combined these three groups into a single family, Exocoetidae, some researchers have continued to recognize them as distinct (but closely similar) families. Flyingfishes may be distinguished from halfbeaks by their more compact bodies, lack of a prolonged lower jaw, and by the noticeably elongate pelvic and/or pectoral fins. Parin (1961) found minor but apparently consistent differences between the Exocoetidae and Oxyporhamphidae and suggested that the genus *Oxyporhamphus* (the only genus which he attributed to Oxyporhamphidae) was more closely related to the hemiramphids than to the exocoetids. There are two major groups of flyingfishes: the four-winged flyingfishes in which both the pectoral and pelvic fins are greatly elongated, and the two-winged flyingfishes in which only the pectoral fins are noticeably enlarged.

The exocoetids, represented by seven genera and 46 species, are primarily surface-dwelling, offshore, oceanic fishes and are found in tropical and temperate waters throughout the world. They are best known for their remarkable aerial flights, the most spectacular of which are made by the four-winged species. According to Stephens (1965) glides of up to 1000 feet or more are possible, but the average gliding distance is probably between 100 and 300 feet. Flyingfishes usually glide 4 or 5 feet above the surface, but flights are reported to reach extreme altitudes of 25 to 36 feet.

Although a number of flying fishes have been reported off Virginia, Maryland, Delaware, and New Jersey, or northward of this area,* there are definite records for only one species, *Cheilopogon heterurus,* within the Mid-Atlantic Bight as defined here. Several subspecies of *heterurus* are recognized, one of which, *Cheilopogon h. doderleini,* occurs in the Sea of Japan.

The eggs of flyingfishes are highly variable. Those of the two-winged species are buoyant and lack attachment filaments, while those of the four-winged species are demersal and have well-developed chorionic filaments. The filaments may be of equal length and evenly distributed over the chorion; may be evenly distributed, but with one filament noticeably longer than the others; may be of equal length and arranged in clusters at opposite poles of the egg; may be in opposing clusters with one filament noticeably longer than the others; or may be in a cluster at one pole with a single, large filament at the opposite pole. All flyingfish eggs lack oil globules.

There are apparently minor differences in eggs of *Cheilopogon heterurus* from the West Indies and Japan (length and possibly number of filaments); but in both of these populations the filaments are distributed evenly over the chorion. In eggs from the Mediterranean attributed to *Cheilopogon heterurus* by D'Ancona (1933) there are 9 to 16 filaments in a cluster at one pole and a single somewhat longer filament at the opposite pole. Larvae described with these eggs do not agree in details of pigment development with larvae from Japan, and it is unlikely that the Mediterranean eggs and larvae are, in fact, conspecific with *Cheilopogon heterurus.*

In yolk-sac larvae of the regional species (*C. heterurus*) the anus lies about three-fifths of the distance of the tail tip, the body is heavily pigmented throughout, and there are well-developed pectoral buds in the smallest specimens de-

***Cheilopogon cyanopterus, exsiliens,* and *frucatus; Cypselurus comatus; Exocoetus obtusirostris* and *volitans; Hirundichthys affinis* and *rondleti; Parexocoetus brachypterus;* and *Progonichthys gibbifrons.*

scribed. In larvae the pectoral and anal fins are relatively large, the dorsal fin is noticeably longer than the anal fin, the jaws are not extended, and the body is

Cheilopogon heterurus (Rafinesque), Atlantic flyingfish

ADULTS

D. 10–15; A. 8–12 [1] (a minimum count of 6 [23] is questioned, JDH); C. 5–6+7+8+6–8; [32] P. 13–17; [1] V. 6 [3] (D., A., and C. counts include juveniles as small as 15 mm SL); predorsal scales 22–38; [1,15] predorsal scales in lateral series 16–24 (count includes some juveniles); lateral line scales 56–60, [14] scales above lateral line 6–9 (count includes some juveniles); [1] gill rakers 5 [13]–8 [23] + 15 [13]–18; [6] vertebrae 42–49 (30–34 + 14–16).[1,3,5,13,15]

Proportions expressed as percent SL (including some juveniles): Preanal length 74.7–81.6, predorsal length 65.3–71.7, pelvic length 51.8–58.2, prepectoral length 20.4–25.4, head length 20.0–27.1, snout length 3.2–8.7, interorbital width 6.9–8.8, pectoral length 39.3–77.8, dorsal height 7.8–23.8, anal height 6.2–13.4, dorsal base 18.0–23.0, anal base 10.7–13.5, greatest depth 14.5–20.3, depth of caudal peduncle 6.3–7.7, body width 11.8–16.2.[1]

Body moderately robust,[12] quadrate; head blunt; [8] mouth terminal, small; maxillary not reaching front of orbit.[18] Teeth unicuspid; premaxillary teeth very small; palatine teeth lacking.[1,11] Pectoral fins beyond anal when depressed, pelvics far forward and about half as long as pectorals, second pectoral ray branched.[11]

Pigmentation: Grayish,[22] dark blue-gray,[11] or brownish black above,[27] silvery on lower sides and belly. Cheeks, operculum, and iris silvery.[22] Dorsal fin little pigmented, and frequently lacking pigment in specimens larger than 150 mm SL; [1] anal fin plain; [12,13] caudal fin gray with

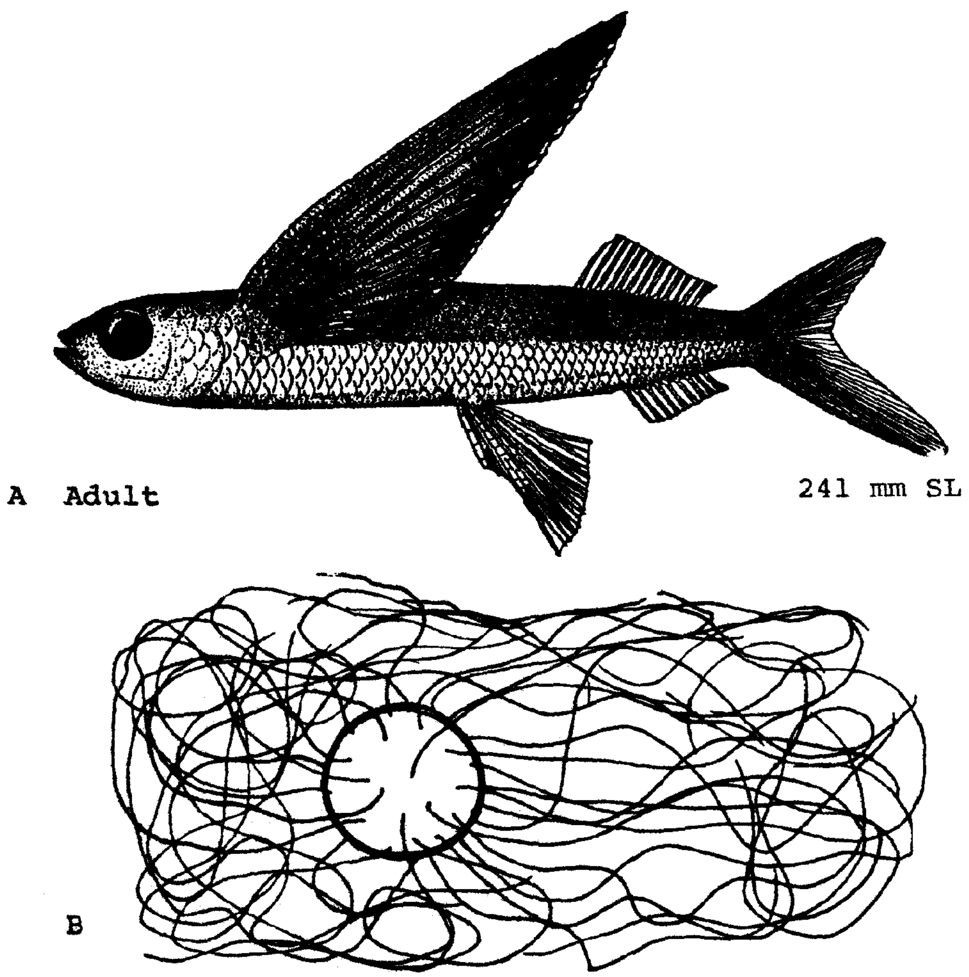


Fig. 55. *Cheilopogon heterurus*, Atlantic flyingfish. A. Adult, 241 mm SL. B. Egg of *Cypselurus heterurus doderleini*, diameter 1.86 mm. (*A, Breder, C. M., Jr., 1938: fig. 29. B, Tsukahara, H.*, et al., *1957: fig. 13.*)

darker streaks;[18] pelvic fins transparent[9] or white,[12,20] slightly dusky at axils,[3] described as lightly pigmented with vague pale crossbands, but nearly clear in many specimens longer than 180 mm SL; pectoral fins dark with pale crossbands and narrow pale posterior margin (at least at sizes greater than 150 mm), crossbands widest mesially and tapering toward anterior margin of fin, triangular in shape; first pectoral ray often lightly pigmented.[1]

Maximum length: 435 mm.[27]

DISTRIBUTION AND ECOLOGY

Range: Tropical and temperate waters of Atlantic; also the Mediterranean Sea,[1] the Red Sea,[28] and represented by a distinct subspecies, *Cypselurus heterurus doderleini*, in Japan.[26] In western Atlantic from the Newfoundland Banks and possibly Sable Island[4,19] south to Rio de Janeiro,[29] including Bermuda.[1] In the eastern Atlantic from Oslo Fjord, Norway,[7] southward, including the English Channel[16] to 4° N.[1]

Area distribution: North in Chesapeake Bay to mouth of Potomac River;[7,10] also coast of New Jersey,[30] and Atlantic coast of Maryland.[31]

Habitat and movements: Adults—a coastal, inshore species;[1,21] sometimes entering bays.[29] Maximum recorded distance from land, 643 km.[1]

Apparently follow currents seasonally in Japan;[25] more abundant in Puerto Rico in winter than summer suggesting inshore-offshore movements.[2]

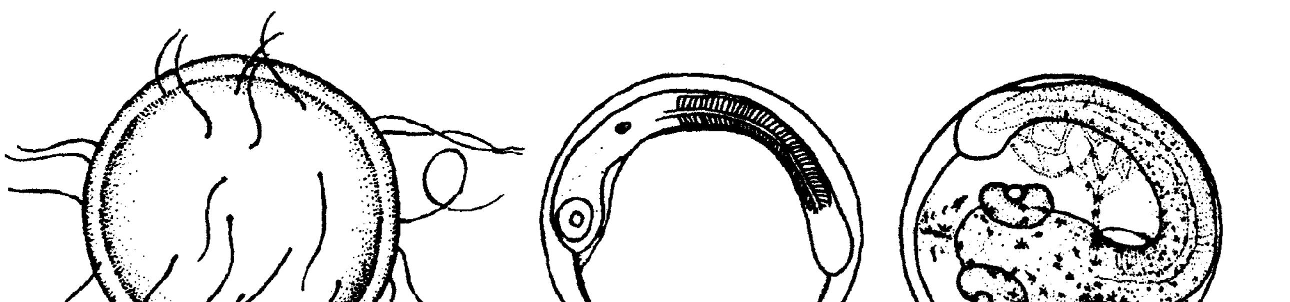
Larvae—swim to surface after hatching, attach to seaweed several days later.[24]

Juveniles—close inshore at surface;[1] begin making short, sporadic gliding flights about 1 month after hatching.[24]

SPAWNING

Location: Coastal waters,[1] sometimes in major channels[17] and near straits.[6]

Season: In Morocco, June and July,[1] also a "ripe specimen" October 5;[13] in Puerto Rico, "developed eggs" April 1;[2] in the Bahamas, ripe eggs in March.[17] A ripe



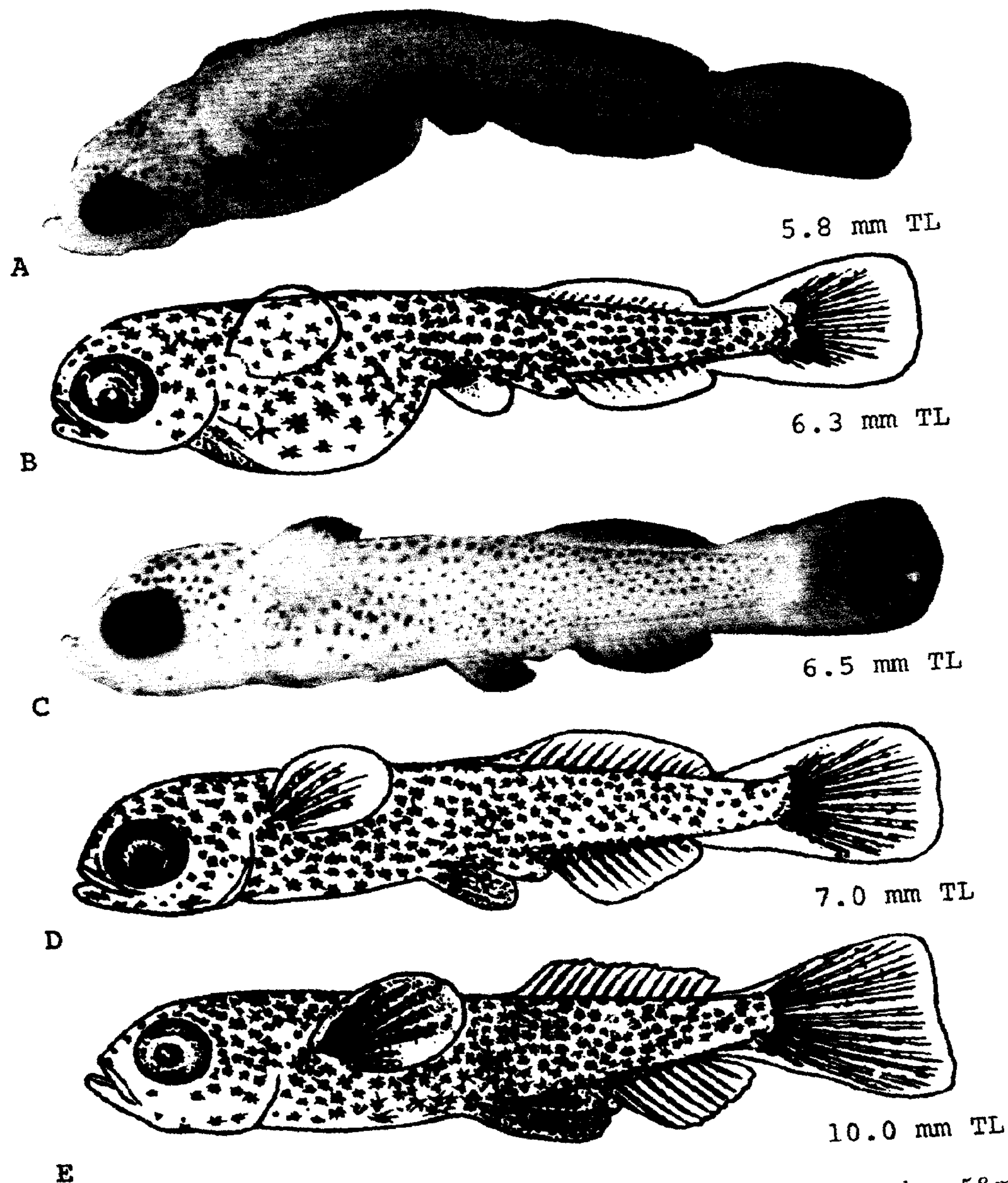


Fig. 57. ***Cheilopogon heterurus***, Atlantic flyingfish. A-E. All specimens from Japan. A. Yolk-sac larva, 5.8 mm TL, pelvic fins developing. B. Yolk-sac larva, 6.3 mm TL. C. Larva, 6.5 mm TL. D. Larva, 7.0 mm TL. E. Larva, 10.0 mm TL. (*A, C, Imai, S., 1958: pl. 37. B, D-E, Tsukahara, H.*, et al., *1957: fig. 13.*)

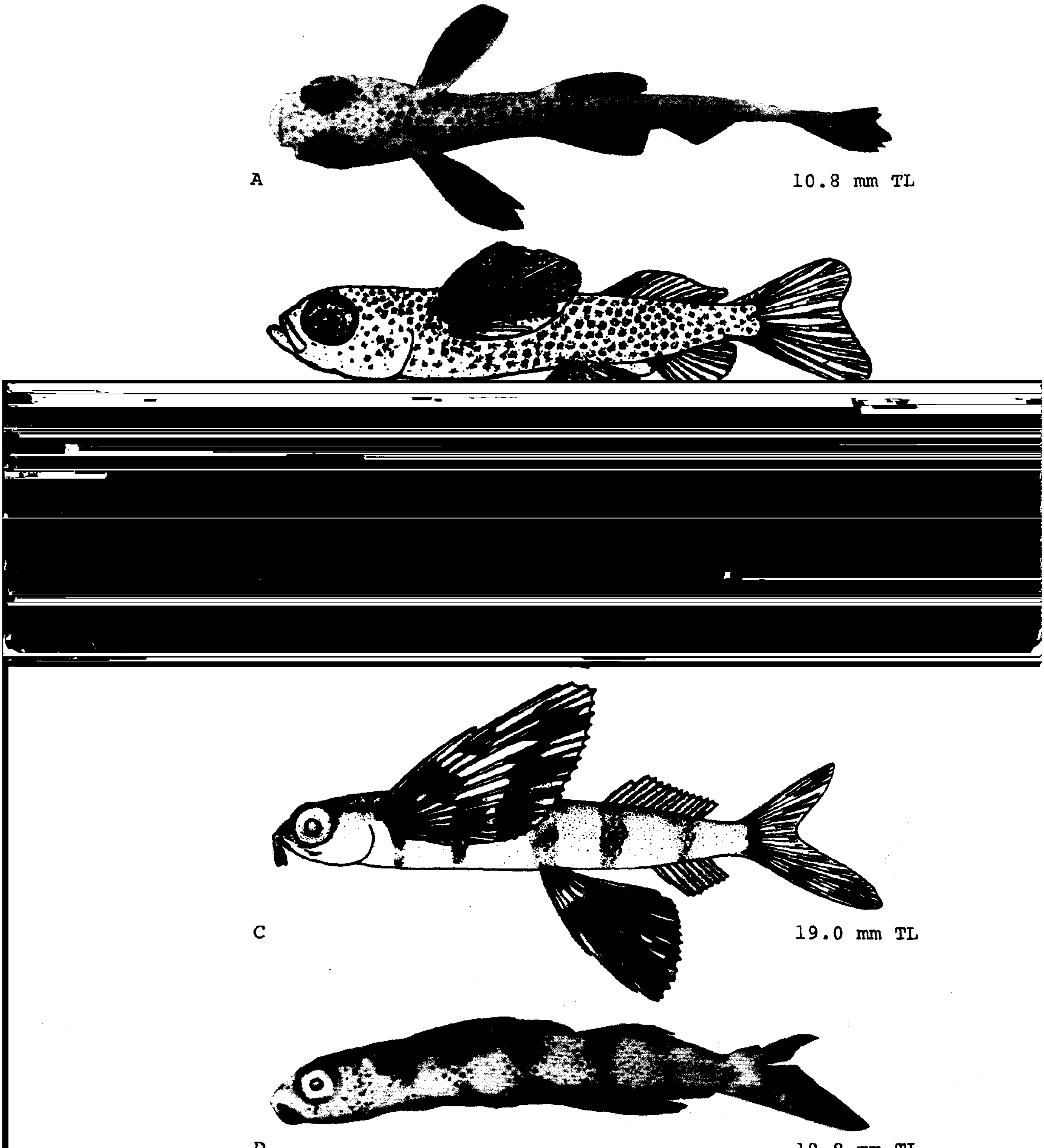
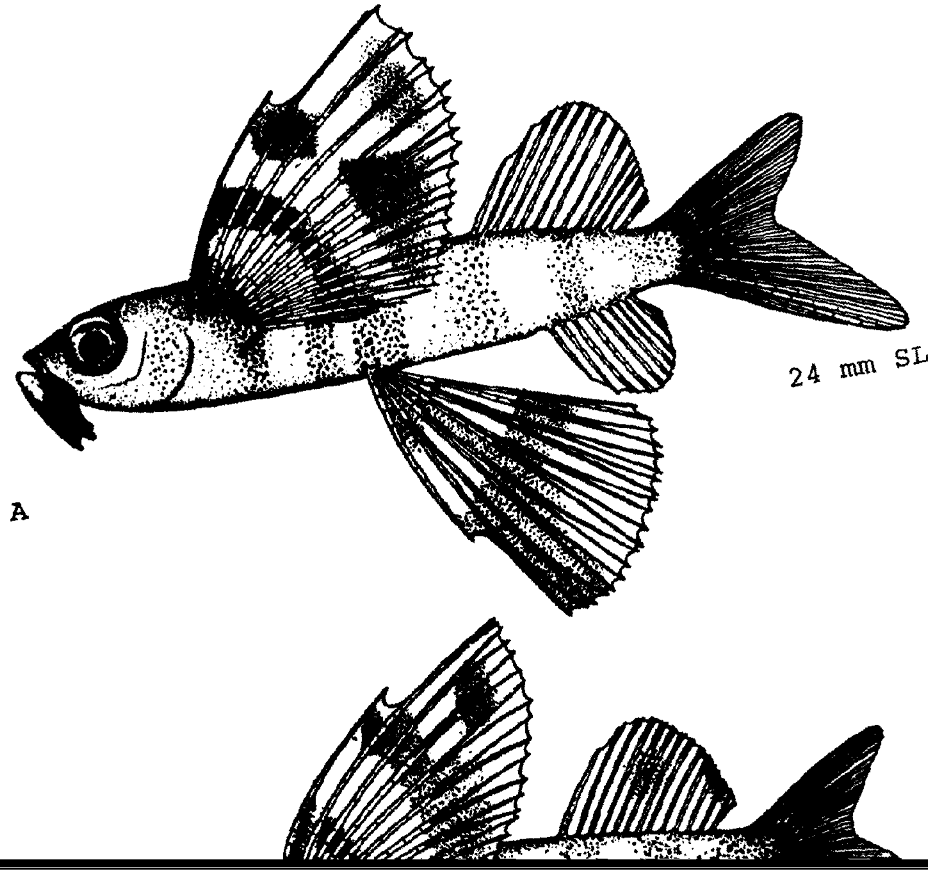
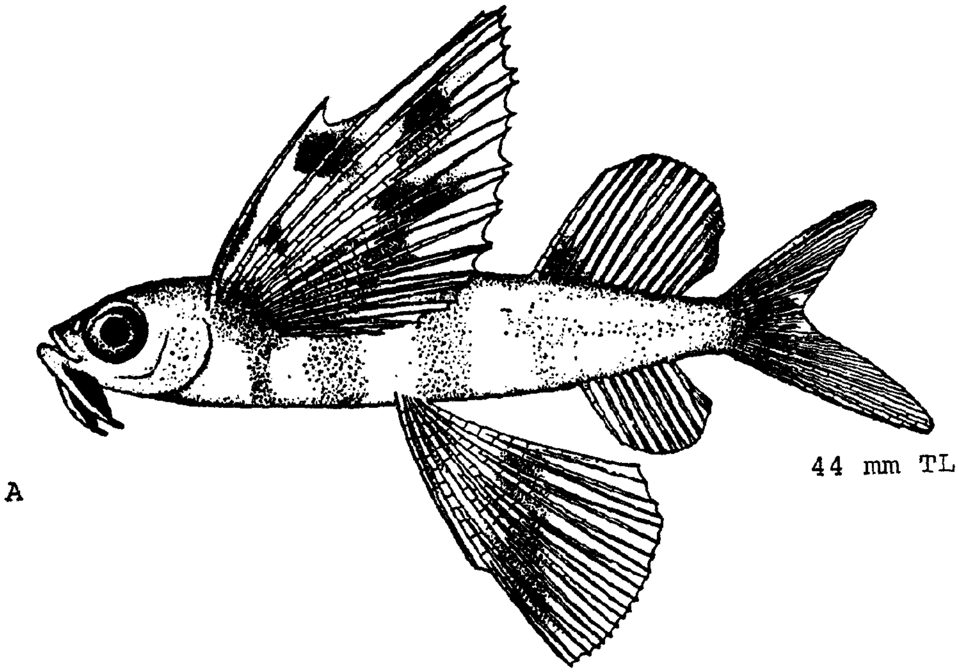
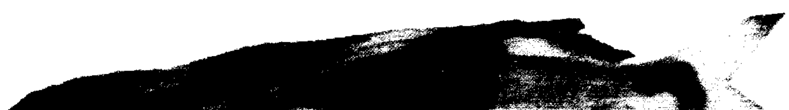
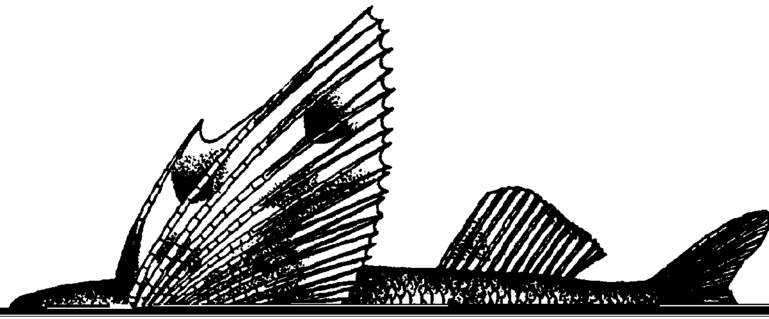


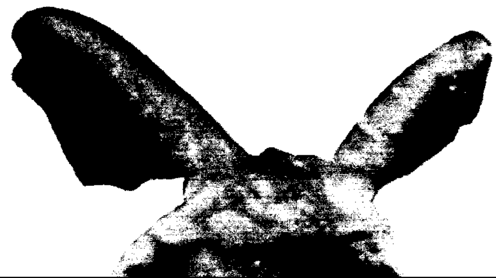
Fig. 58. *Cheilopogon heterurus*, Atlantic flyingfish. A-D. All from Japan. A. Larva, dorsal view, 10.8 mm TL. B. Larva (or early juvenile), 14.0 mm TL. C. Juvenile, 19.0 mm TL, barbels formed, banded pattern established.


24 mm SL
A

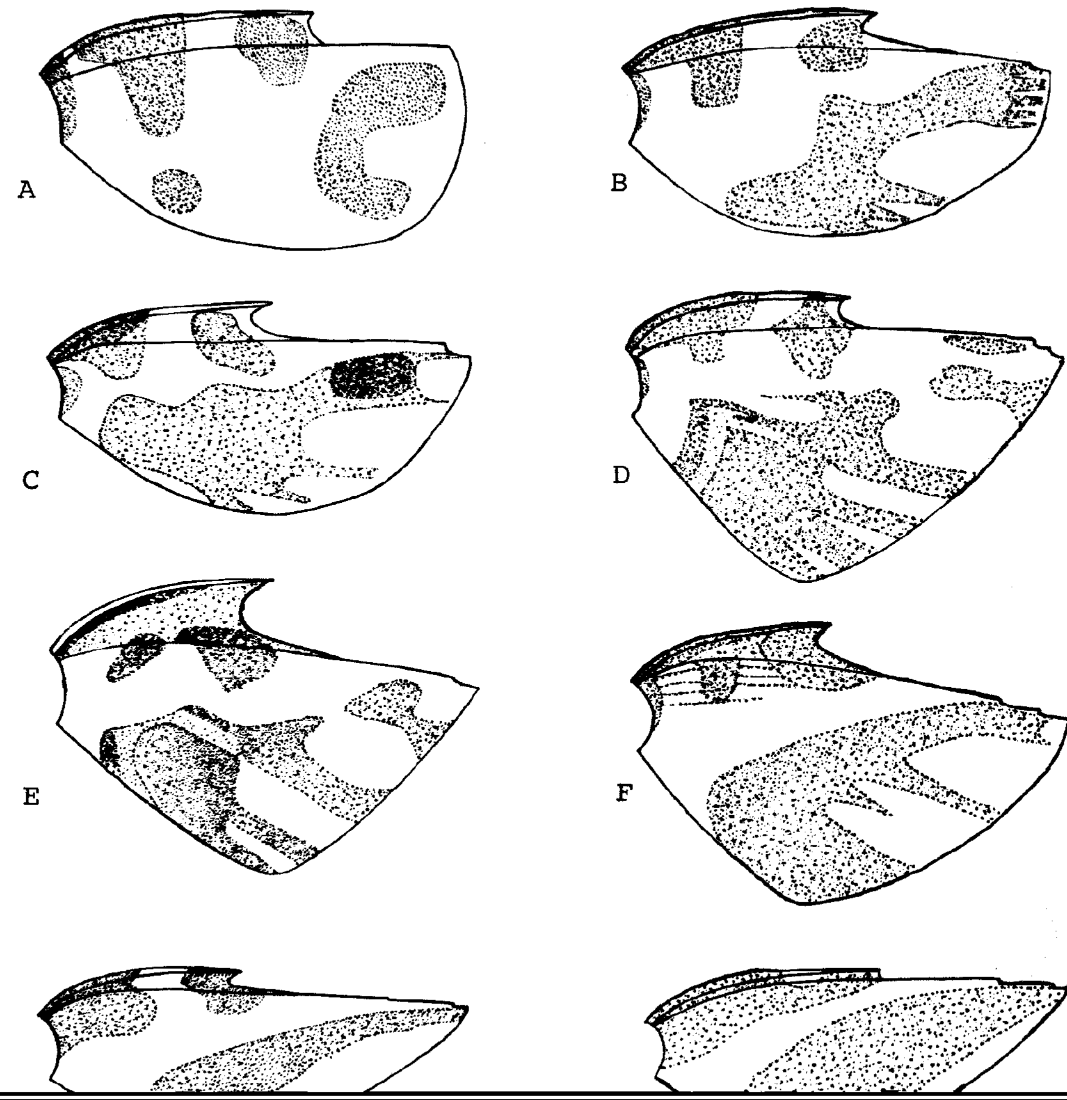

44 mm TL
A







broad vertical pigment bands on sides and belly; dorsal surface pale and lacking bands. Banded pattern retained to at least 80 mm SL. By ca. 125 mm SL back dark, belly silvery as in adult.[1] At 175 mm TL dorsal fin uniform grayish, anal unpigmented.[13] Pectoral and pelvic fins highly variable with development (see figures 64 and 65); [1] at 140 mm pectoral fin essentially dark with light median band.[15] In small juveniles lower lobe of caudal clear with a dark spot at base and another on distal half; upper lobe frequently devoid of pigment to


A
B
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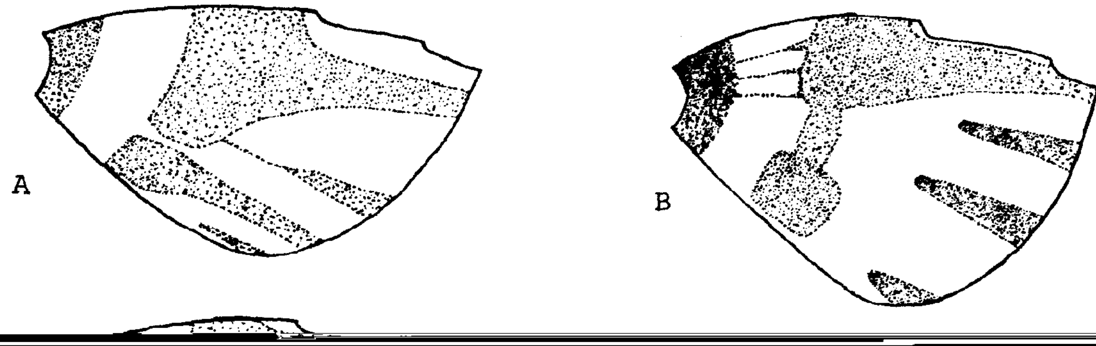
F



[redacted]

Euleptorhamphus velox
Hemiramphus brasiliensis
Hyporhamphus unifasciatus

halfbeaks

FAMILY HEMIRAMPHIDAE

Although the halfbeaks were recently placed in the family Exocoetidae by [redacted]

Euleptorhamphus velox Poey, Flying halfbeak

ADULTS

D. 20 [10]–25; [17] A. 21–22; C. branched rays 7 upper, 6 lower; [3,5] P. 6 [10]–7 or 8; V. 6; [2,3] lateral line scales ca. 139–144; predorsal scales 53–55; gill rakers on first arch 7–8 + 24–26; [5] vertebrae 69–73.[19]

Body elongate, compressed, band-like, subcarinate; [3,9] lower jaw greatly elongate (JDH); teeth on lower jaw longer than those on upper jaw; [5] pectoral fins elongate.[4]

Pigmentation: Light brown or olivaceous above; sides from upper edge of pectoral base downward bright silvery.[3,9]

Maximum length: Ca. 610 mm.[4]

DISTRIBUTION AND ECOLOGY

Range: In the western Atlantic, Nantucket, Massachusetts [8,13,15] south through Gulf of Mexico and the Caribbean to Recife, Brazil; in the eastern Atlantic from Cape Verde Islands and Nigeria,[2] also South Africa.[16,17]

Area distribution: Coastal waters of New Jersey.[6,11,20]

Habitat and movements: Adults—a pelagic,[7] gliding,[14] marine species recorded inshore over shallow reefs [7] and in lagoons.[12]

Larvae—no information.

Juveniles—a juvenile 27.9 mm long recorded off southeastern United States near 180 m depth contour.[18]

SPAWNING

Location: Unknown.

Season: Well-developed eggs in a female collected May 1 in Puerto Rico.[1]

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

AGE AND SIZE AT MATURITY

A 190 mm female contained ripe eggs.[16]

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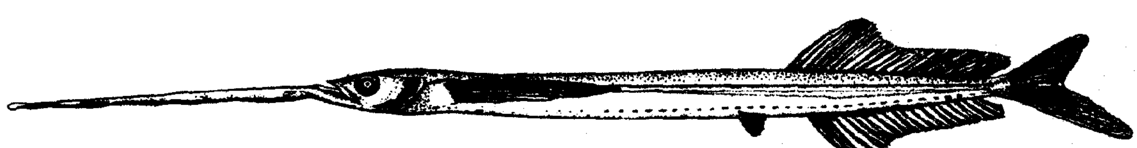


Fig. 66. *Euleptorhamphus velox*, Flying halfbeak. A. Adult, 135 mm SL. (*A, Collette, B. B., 1965: fig. 2.*)

Hemiramphus brasiliensis (Linnaeus), Ballyhoo

ADULTS

D. 12–15; A. 11–15; [1,10] scales along body 53 [8,12,16]–61; [3] total vertebrae 52–55; preanal vertebrae 34–37; caudal vertebrae 16–18; total gill rakers first arch 28–38; second arch 20–30.[1]

Proportions expressed as percent SL: Body length (posterior edge of opercle to base of caudal, 78.2–79.7; longest pectoral ray, 15.7–16.4; pectoral insertion to pelvic base, 42.6–43.3; pelvic insertion to caudal base, 33.3–35.3; distance from snout to tip of lower jaw, 29.1–31.6; depth at pectoral insertion, 12.9–13.7; depth at pelvic insertion, 13.1–13.6.[27] Proportions as times in SL: Head 4.3–4.6, depth 5.4–6.3.[12] Depth 6.75 times in length excluding jaw.[17]

Body rather robust,[13] elongate, compressed,[12] deeper than wide; [13] sides nearly parallel and vertical; [2] back more or less rounded.[13] Head rather low,[12] mandible produced into long beak terminating with a fleshy flap.[16] Teeth short,[12] in broad bands on premaxillary plate, rim of mouth, and lower jaw, lacking on beak.[13] Air bladder cellular.[2,13] Sensory canal on postorbital branched. Upper jaw naked.[22]

Dorsal in advance of anal origin, its base 1.5–2.1 times that of anal base; [22] caudal deeply forked, the lower lobe much longer than the upper; [17,22] pectoral fin length less than distance from base of uppermost pectoral ray to posterior end of nasal fossa; [1] pelvics inserted scarcely in front of dorsal [2] and nearer hypural than gill opening.[13]

Pigmentation: Rich deep bluish green,[8,17] dusky greenish brown,[9] or dark greenish above; [16] sides and belly bright silver [12] or silver-white; however, dorsal and ventral colors may end abruptly in mid-lateral region [16] and mid-lateral region may be marked with a dark streak which becomes wider and more diffuse posteriorly; midline of back with 3 narrow bands, all obscure, the central one often diffuse; [9] beak blackish, its tip bright orange or scarlet, and its membrane white-edged; [8,17] upper caudal lobe reddish orange,[1,4] deep orange,[8] orange,[9] or yellow; lower lobe of caudal olivaceous; inner edge of both caudal lobes dark; [16] lobe of dorsal deep orange or orange-yellow; pelvics tipped or edged with yellow.[8,17]

Maximum length: Ca. 381 mm TL.[4]

DISTRIBUTION AND ECOLOGY

Range: Both sides of the Atlantic; [23] in the western Atlantic: Woods Hole, Massachusetts,[1,15,21] to Rio de Janeiro, Brazil, and throughout the Gulf of Mexico and the West Indies; absent in Bermuda; in the eastern Atlantic from the Cape Verde Islands and Dakar south to Luanda, Angola; [1,10] also elsewhere in Africa.[25,26]

Area distribution: Coastal waters of New Jersey [5,24] and in Maryland [6] and Virginia waters of Chesapeake Bay.[7,11,18]

Habitat and movements: Adults—coastal,[23] found in shallow water [7] and easily attracted to lights at surface at night; [14] sometimes enter harbors [17] and sometimes washed ashore.[20] In Florida inshore in November and again in January.[19]

Larvae—recorded from low salinity canals and creeks. Minimum salinity, 1.5–2.1 ppt.[27]

Juveniles—pelagic; [10] recorded from various Bahamian islands in March; [14] sometimes carried by Gulf Stream north of normal adult range.[10] Juveniles 23.0–78.2 mm long recorded in Atlantic Ocean near 180 m depth contour.[28]

SPAWNING

No information.

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

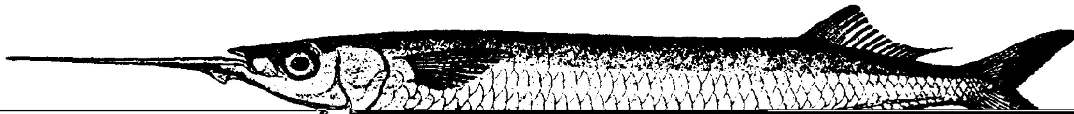
LARVAE

Size range described, 8.0 [2]–13.5 mm SL.[27]

Myomeres 37 + 17 = 54.[27]

Proportions as percent SL (at 13.0–13.5 mm SL): Posterior edge of opercle to base of caudal, 79.2–80.7; longest pectoral ray, 14.2–15.8; pectoral insertion to pelvic insertion, 38.7–39.3; pelvic to caudal base, 35.0–35.9; depth at pectoral base, 7.60–9.20; depth at pelvic insertion, 6.50–7.10.[27]

Body elongate, shallow, compressed. Beak first evident in a specimen 13.0 mm SL, not so in another at 13.5 mm SL. Choroid fissure evident throughout stage. Preanal finfold extended well anterior to pelvic insertion. At 13.0–13.5 mm SL all fin rays ossified except ventralmost



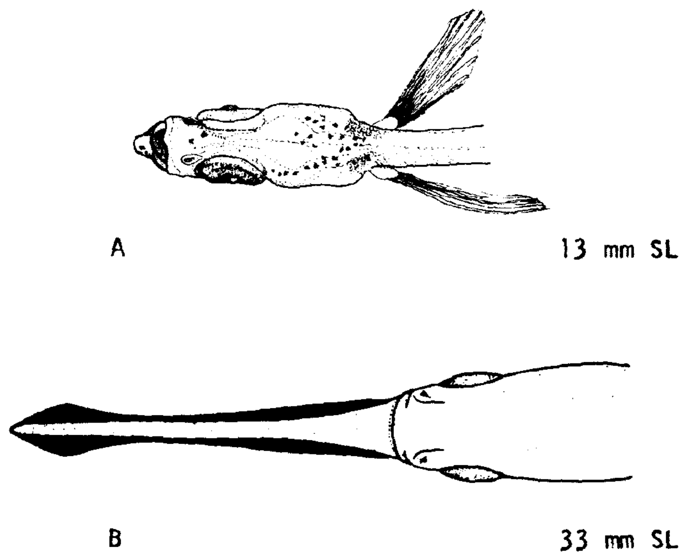


Fig. 68. *Hemiramphus brasiliensis*, Ballyhoo. Development of head. A. 13 mm SL, lower jaw not protuberant. B. 33 mm SL; lower jaw, lappets well-developed. (*A, Hardy, J. D., Jr., and R. K. Johnson, 1974: fig. 2. B, Breder, C. M., Jr., 1934: pl. 6.*)

pectoral rays; lower caudal lobe longer than upper. Urostyle oblique throughout stage.[27]

Pigmentation: At 8.0–10.0 mm frequently plain brick red, fins transparent, beak with black tip.[2] At 13.0–13.5 mm SL scattered large melanophores on dorsal surface of head, especially on occiput; few scattered melanophores on cheeks. Pigment along middle of back limited to two obscure rows of melanophores, each row slightly lateral to dorsal midline and extending from occiput to caudal base. Scattered large melanophores on posteriormost portion of dorsal and anal fin; other fins lacking pigment except for several large melanophores at base of pectoral fin. Mid-lateral stripe present, but extremely obscure, consisting of a single row of small, widely spaced melanophores. In a 13.0 mm specimen a sheath of scattered melanophores dorsal and lateral to gut.[27]

JUVENILES

Minimum size described: 35.0 mm.[2]

Gill rakers 29–31 in specimens 32.0–50.0 mm SL.[10]

Beak of young with mandibular fold similar to that of *Tylosurus crocodilus* well-developed at least by 33.0 mm SL.[3]

Proportions as percent SL (at 46 mm SL): Body length (posterior edge of opercle to caudal base), 78.9; longest pectoral ray, 15.9; pectoral insertion to ventral insertion, 43.3; pectoral insertion to caudal base, 35.2; tip of snout to tip of lower jaw, 28.2; depth at pectoral fin, 12.0; depth at pelvic fin, 12.0.[27] Proportions as times in TL: Depth, at 35 mm, 9.2, at 38.5 mm, 7.7.[9] Lower jaw longer than upper in specimens 40–120 mm SL, about equal at 100–200 mm SL.[1] Base of dorsal fin 1.3–1.4 times base of anal in "young."[22]

Scales fully formed in a specimen of 46 mm SL.[27] Posterior rays of dorsal extended into a darkened lobe at least by 38.0 mm.[2]

Pigmentation: In a 35.0 mm specimen from Tortugas, Florida, long vertical bars developing on sides; upper caudal lobe reddish; some individuals with median dorsal line of pigment.[2] In a 40.0 mm specimen from Haiti submedian dorsal lines evident as series of dots. In Haitian specimens 35.0–47.0 mm long pigmented scale edges obscured by general darkening of dorsum; top of head, snout, and lower jaw densely covered with chromatophores; opercles with few scattered pigment cells; edges of scales on dorsal surface as far down as center of sides densely pigmented; a dark band on side beginning at upper angle of gill opening, continuing to caudal fin, becoming wider and denser posteriorly; belly and undersurface with median band of chromatophores extending from isthmus to caudal fin, most intense immediately before and between pelvics, splitting in two at anus and continuing as a line of spots on either side of anal to caudal; a small black spot on body at base of ventral fin; three dark patches on middle of side, two between anal

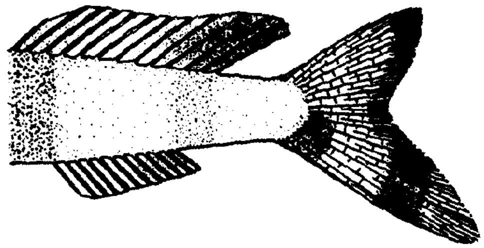


Fig. 69. *Hemiramphus brasiliensis*, Ballyhoo. A. Juvenile, 33.0 mm SL, median fins. (*A, Breder, C. M., Jr., 1934: pl. 6.*)

and dorsal, one above ventral, and a faint trace of a fourth spot just anterior to last large spot; few scattered chromatophores on lower sides; membrane of posterior part of dorsal and anal blackish; lower lobe of caudal dusky; other fins plain.[9] In a specimen from Chesapeake Bay 46.0 mm SL, pigment well-developed on snout, interorbital area, occiput, cheeks, upper and lower jaws, and mandibular folds of beak. Back with 3 distinct stripes, 1 along dorsal midline and extending from occiput to caudal base, and 2, 1 on each side, lateral to it and extending only to dorsal base. Scale pockets above lateral line edged with pigment. Mid-lateral stripe well-developed, divided into 3 portions; a narrow but intense row of melanophores on horizontal septum from gill cover to caudal peduncle; a wider band of melanophores dorsal to horizontal septum likewise extending from gill cover to caudal peduncle; a similar band of melanophores ventral to horizontal septum extending from a vertical through pelvic base to caudal peduncle. A band of widely scattered melanophores covering most of ventrolateral surface of body ventral to mid-lateral stripe. A single band of small melanophores along mid-ventral line of body, extending from isthmus to anus, dividing at anus, and continuing as a line of spots on either side of anal base to bases of procurrent caudal rays. A band of fine melanophores at mid-ventral line of body on caudal peduncle. Pigment present at bases of all fins and extending over rays and membranes of all but pectoral fins, with especially dense pigmentation covering posteriormost portions of dorsal and anal fins and membrane between ventral caudal rays.[27]

AGE AND SIZE AT MATURITY

No information.

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Hyporhamphus unifasciatus (Ranzani), Halfbeak

ADULTS

white, venter silvery;[1,9,15,23] dorsal scales with dark

[redacted]

represent a distinct species. If so, its range extends southward only to mid-peninsular Florida and from the Florida panhandle to Mexico (BBC).

Habitat and movements: Adults—a pelagic schooling species [15,35] found in surface water at night; [4] recorded from shallow shore zones over sandy bottoms,[5,12,24] in bays,[16] in harbors near shoals and sandy islands,[23] among islands (as in Florida Keys),[25] in channels,[26] and from brackish water in lower parts of streams.[15] Sometimes washed ashore in large numbers.[23] Salinity range 7.5 [11,16]–42.9 ppt. Recorded temperature range 16.0 [37]–34.9 C (although this may include some juveniles).[39] Apparently make inshore-offshore movements along Atlantic and Gulf coasts: in Chesapeake Bay region inshore in April, offshore (and possibly southward to warmer water) in fall.[8] Inshore in July, August, and September in New England; [20] August and September in Great South Bay, New York; [1] April to November in North Carolina; [10] November and September in Tampa Bay, Florida; [11] "late summer" to "early fall" in Texas.[29]

Larvae—possibly on bottom [15] (but this is questioned, BBC). Salinity range 0–12.0 ppt.[33]

Juveniles—found in schools; [38] a single 23.0 mm specimen from near the 180 m contour in Atlantic Ocean; [34] specimens 39.0–46.0 mm long in inlets in vicinity of Fire Island in August; [31] at 41.0–52.0 mm inshore along beaches; [38] specimens 45.0-127.0 mm long in Alligator Harbor, Florida from July until "fall." [17] Maximum recorded salinity, 31.6 ppt; maximum recorded temperature 23.3 [40] or, possibly, 34.9 C.[39]

SPAWNING

Location: In Puerto Rico, eggs found on shallow turtle-grass beds (FDM).

Season: Summer in Chesapeake Bay [6,8] (a recently hatched specimen was recorded from the bay on July 8 [15]); ripe female on March 5 in Haiti.[9]

Fecundity: Unknown.

EGGS

Location: Semibuoyant.[15]

Ripe ovarian eggs: Diameter 1.0 mm.[9]

Fertilized eggs: Diameter ca. 2.0 mm, almost transpar-

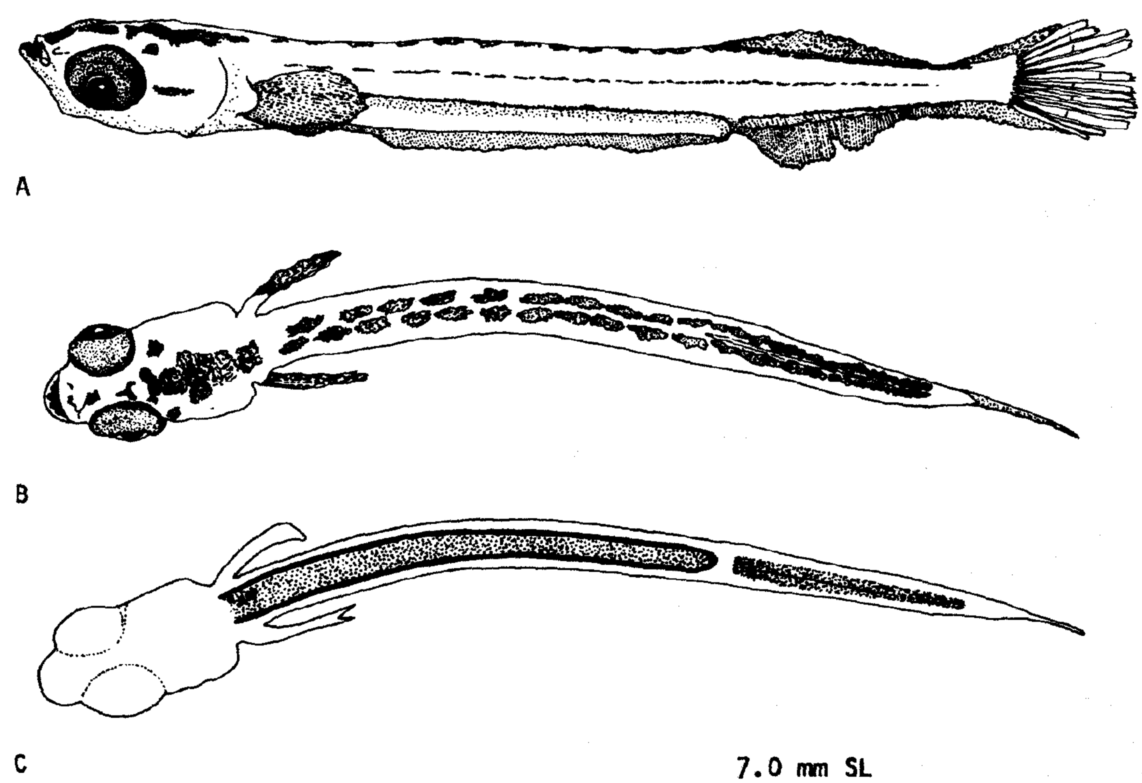

Fig. 71. *Hyporhamphus unifasciatus*, Halfbeak. A. Larva, 7.0 mm SL. B. Dorsal view of A. C. Ventral view of A. (*A, B, Hardy, J. D., Jr., and R. K. Johnson, 1974: fig. 2. C, Original drawing, J. D. Hardy, Jr.*)

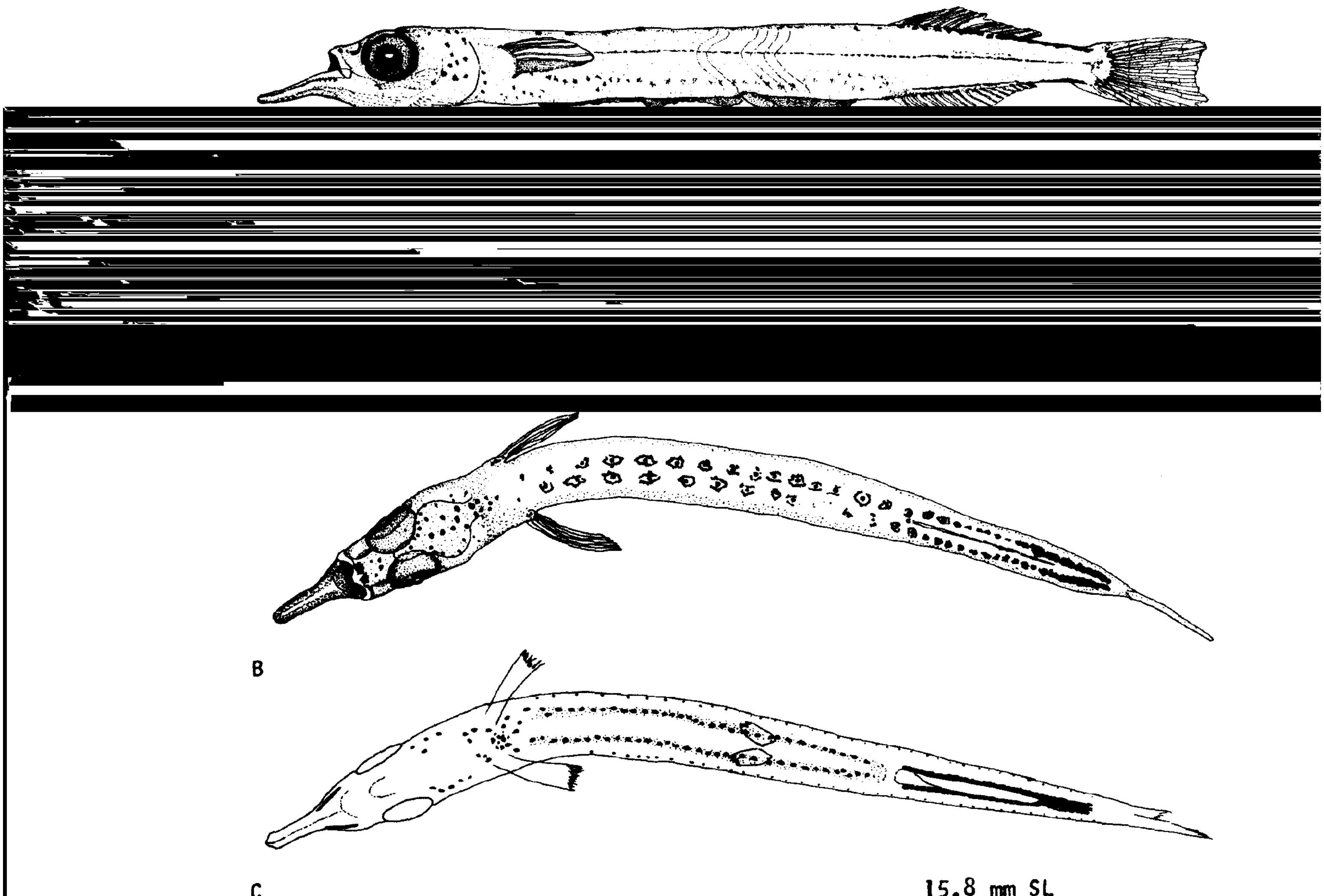

Fig. 73. *Hyporhamphus unifasciatus*, Halfbeak. A. Larva, 15.8 mm SL. B. Dorsal view of A. C. Ventral view of A. (*A, B, Hardy, J. D., Jr., and R. K. Johnson, 1974: fig. 2. C, Original drawing, J. D. Hardy, Jr.*)

Pigmentation: At 7.0 mm SL dorsal surface of head with 3 patches of pigment: a small patch just behind upper jaw, a somewhat larger one between eyes, and a larger one on occiput. Tip of lower jaw heavily pigmented. A row of dark spots, their borders distinctly outlined with dark pigment, along each side of midline of back from just posterior to pectoral bases to caudal base. Anterior to dorsal fin, dorsal spots oblong and usually well separated; along base of dorsal spots typically fused or separated by narrow, complete or incomplete, transverse bars of unpigmented skin. Eye heavily pigmented. A series of melanophores from posterior margin of eye to posterior margin of head. Mid-lateral stripe present as thin, dashed line from back of head to last evident caudal myomere. A dense continuous row of pigment along each side above gut connecting to each other just anterior to anus.[32] Gut pigmented (JDH). A row of fused pigment spots along each side of anal fin. Three small groups of melanophores near mid-ventral line between pectoral bases. At 7.5 mm SL pigment more intense, except ventrally. At 9.5 mm TL dorsal pigment in two more or less discrete rows from head to caudal fin, melanophores on gut stellate, more numerous than in previous stages dated posteriorly to form continuous pigment bands from dorsal origin to caudal base, gut heavily pigmented, a solid line of dark pigment ventrally from anus to caudal base; a conspicuous pigment spot on caudal peduncle and four spots on caudal base; melanophores scattered over head and beneath eye; a large bar of pigment behind and below eye (WLD). At 15.5 mm 2 submedian dorsal lines indicated by series of unconnected pigment spots (based on West Indian specimens).[9] At 15.8 mm SL rows of pigment along gut broken into discrete spots (JDH), dorsal spots faintly outlined with dark pigment, fins without pigment.[32] At 19.0 mm (West Indies) median dorsal line faintly indicated by series of small widely spaced chromatophores. In "very young fish" (stage indefinite) lateral spots apparently each formed by a single, large chromatophore.[9]

JUVENILES

Minimum length described, 22.5 mm SL.

Proportions expressed as percent SL (length range 22.5–130.6 mm): Body length (posterior edge of opercle to

Fig. 74. *Hyporhamphus unifasciatus*, Halfbeak. A. Juvenile, 83.5 mm TL. (*A, Böhlke, J. E., and C. C. G. Chaplin, 1968: 126, © Academy of Natural Sciences of Philadelphia. Used with permission of authors and publishers.*)

14.5; *pectoral insertion to pelvic insertion* 30.6–36.3; pelvic insertion to base of mid-caudal rays 38.4–47.2; lower jaw length (snout to tip of lower jaw) 21.4–29.8; body depth at pectoral insertion 10.4–13.4; depth at pectoral tip 9.8–14.6; depth at pelvic insertion 10.5–14.8.[32]

"Young" more slender than adults; [19] beak well-developed at 25.0 mm, proportionately longer in specimens 100–200 mm long than in larger specimens; [15] mandibular lappets evident by at least 38.0 mm; posterior half of dorsal fin low, never elevated into distinct lobe.[2]

Pigmentation: At 23.5 mm two rows of large black spots on back; pigment developed on dorsal fin and on basal third of caudal fin.[32] At 28.0 mm (West Indian specimen) number of chromatophores in median dorsal line noticeably increased. At 32.0 mm (West Indian) two submedian dorsal lines developed as elongate dashes of pigment. At 52.0 mm (West Indian) dashes of submedian lines consolidated into stripes typical of adult. At 85.0–95.0 mm (West Indian) lateral spots, seen in earlier stages, completely obliterated. In a 95.0 mm West Indian specimen scale edges pigmented.[9]

AGE AND SIZE AT MATURITY

Minimum size reported, a 147 mm female (West Indian).[9]

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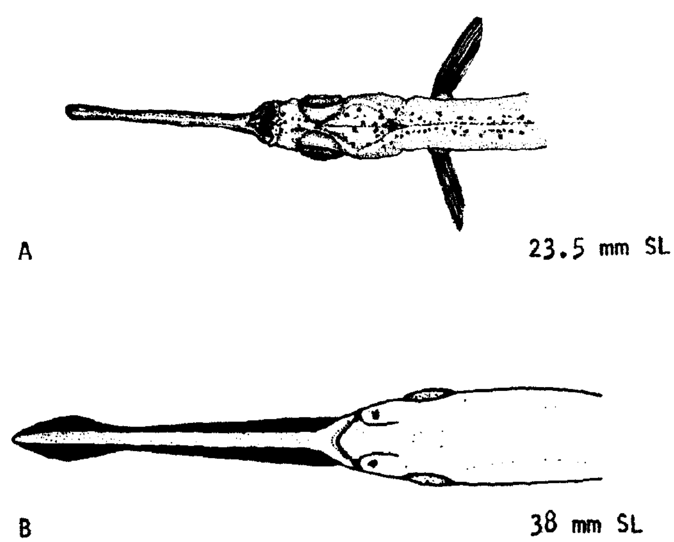

Fig. 75. ***Hyporhamphus unifasciatus***, Halfbeak. Development of head. A. 23.5 mm SL. B. 38 mm SL. (*A, Hardy, J. D., Jr., and R. K. Johnson, 1974: fig. 2. B, Breder, C. M., Jr., 1934: pl. 6.*)

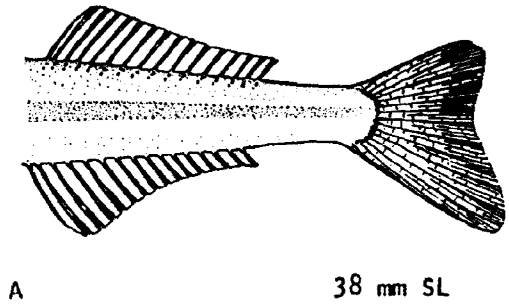

Fig. 76. *Hyporhamphus unifasciatus,* Halfbeak. A. Details of morphology and pigmentation of caudal region at 38 mm SL. [redacted]

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[redacted]

Cyprinodon variegatus
Fundulus confluentus
Fundulus diaphanus
Fundulus heteroclitus
Fundulus luciae
Fundulus majalis
Lucania parva

killifishes
Cyprinodontidae

FAMILY CYPRINODONTIDAE

Cyprinodontid fishes, of which there are about 45 genera and 300 species, occur on all continents except Australia. Although they are mostly freshwater species, some occur in brackish water, and others occasionally enter coastal marine waters.

Killifishes are characterized by lack of a lateral line, a terminal and protrusible mouth, well-developed teeth in jaws, the upper surface of the head conspicuously flattened, and the dorsal fin positioned far back over the anal fin. Sex dimorphism is common in the group, especially in relation to color pattern and relative fin lengths. Males of many species develop contact organs during

Key to eggs of cyprinodontid fishes of the Mid-Atlantic Bight.

1A. Chorion essentially smooth, lacking bristles and/or attachment filaments, or with very small, inconspicuous filaments 2

1B. Chorion equipped with bristles and/or long well-developed attachment filaments 3

2A. Chorion perfectly smooth; egg opaque, deep amber or orange; diameter 2.0–3.0 mm .... *Fundulus majalis*

2B. Chorion essentially smooth, but usually with few poorly developed filaments; egg nearly or completely transparent; diameter 1.5–2.5 mm; limited to Atlantic coastal areas from North Carolina to Delaware .... *Fundulus heteroclitus* (in part)

3A. Chorion with well-developed attachment filaments, but lacking bristles 4

3B. Chorion with both bristles and attachment filaments 7

4A. Attachment filaments not evenly distributed over chorion, definitely concentrated in one area; few (8–15) relatively large oil globules; diameter 1.0–1.3 mm .... *Lucania parva*

4B. Attachment filaments more or less evenly distributed over chorion 5

5A. Yolk with one very large oil globule and many minute ones, diameter 1.0–1.7 mm .... *Cyprinodon variegatus*

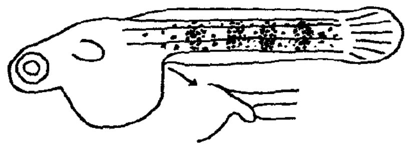
5B. Oil globules of various sizes, but no single globule conspicuously larger than the others 6

6A. Attachment filaments numerous, in very thick flattened mat completely surrounding eggs, egg diameter 1.5–2.5 mm .... *Fundulus heteroclitus* (in part)

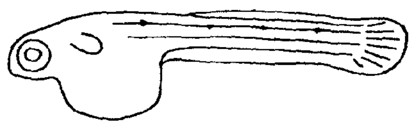
6B. Attachment filaments sparse, matted; egg diameter ca. 1.7–2.3 mm .... *Fundulus diaphanus*

7A. Chorionic bristles numerous, crowded; egg

2B. Lateral melanophores forming obscure blotches, anus extended slightly beyond contour of finfold; finfold not nicked; myomeres 8 + 16 ..... *Cyprinodon variegatus*



3A. No pigment immediately below vertebral column, pigment absent or poorly developed above notochord, no pigment in pectorals, myomeres 9–10 + 23–25 .... *Fundulus diaphanus*

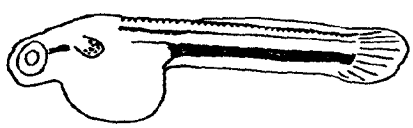


3B. Pigment immediately below vertebral column 4

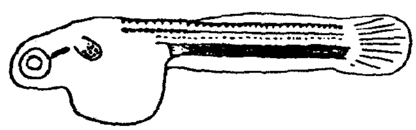
4A. Entire area below vertebral column heavily pigmented, or at least darker than remainder of body; pectorals pigmented 5

4B. Area below vertebral column with discrete bands of pigment rather than entirely pigmented 6

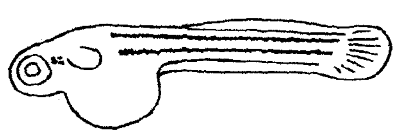
5A. No mid-lateral line of melanophores, myomeres 9–10 + 21–24 .... *Fundulus confluentus*



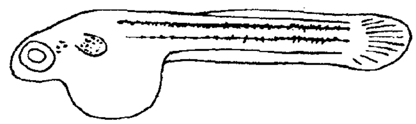
5B. A faint dashed line of melanophores midlaterally, myomeres 8–9 + 21 .... *Fundulus luciae*



6A. No pigment in pectoral fins; total length 7.0 to 11.0 mm (at minimum size, yolk sac large, conspicuous); myomeres 10 + 24 .... *Fundulus majalis*



6B. Pectoral fins pigmented; total length 4.0 to 7.3 mm (at maximum size, yolk nearly absorbed, inconspicuous); myomeres 9 + 24 .... *Fundulus heteroclitus*

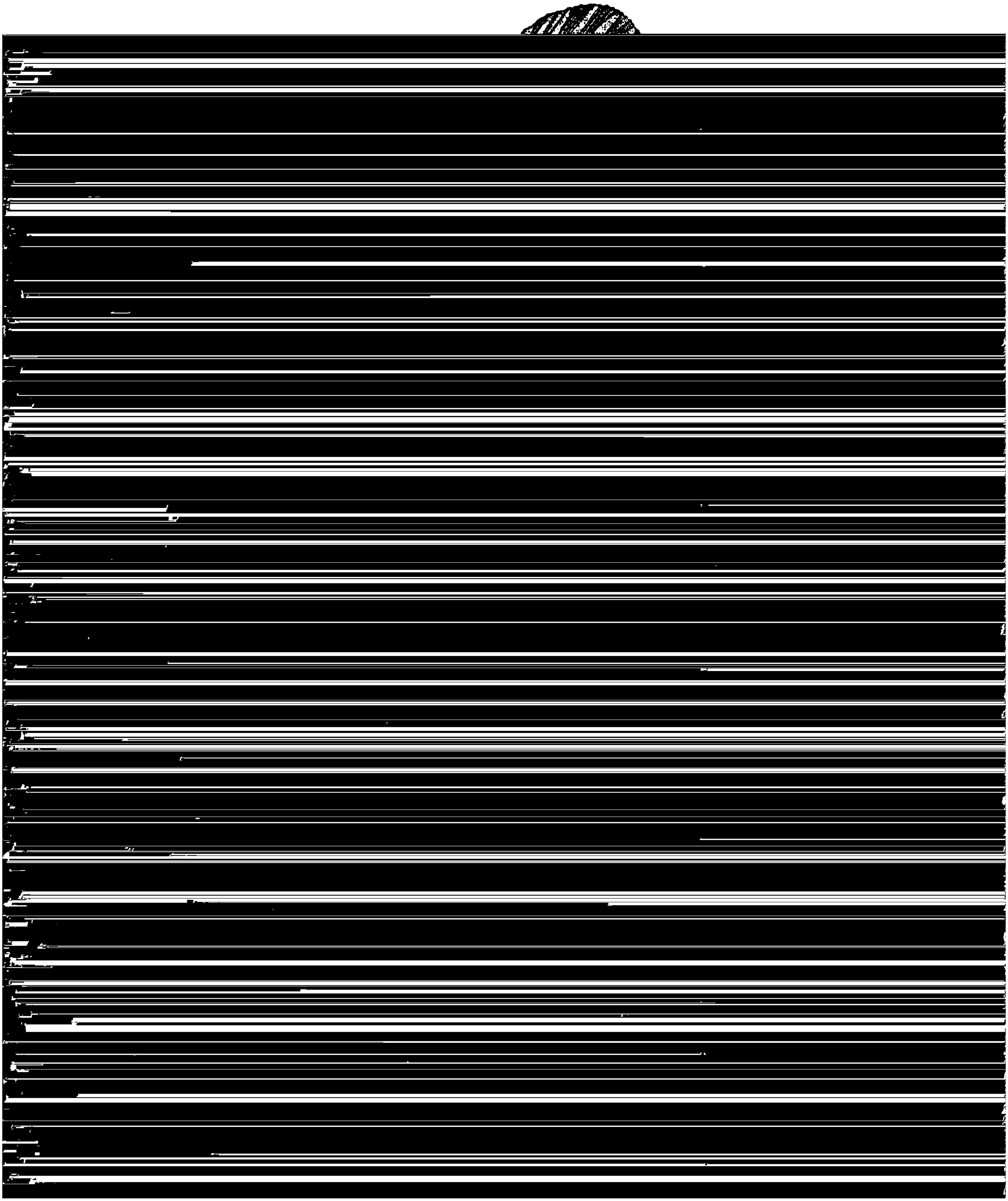


Cyprinodon variegatus Lacépède, Sheepshead minnow

ADULTS

D. 9–13; A. 9–12; [12,16,22,53] C. total rays 28–29,[72] principal rays 14–16; P. 14–17; V. 5–7; lateral scale rows 24–29 [12,16,22,53] (counts of 20–22 [61] are questioned [16]); pre-

ish or white; [14,26] cheeks brassy; lower jaw blue.[23] Dorsal olive or dusky with 1 or 2 prominent dark ocelli on posterior rays; anal and pelvics usually clear or pale yellowish with white margins; pectorals clear, dusky, or orange; caudal greenish, dusky, or dull reddish with dark



in shallow, gently flowing streams over bottoms of sand, black silt, or mud. Males occupy territories up to 0.3–0.6 m in diameter and may or may not construct nest pits. Pits, when constructed, 10–15 cm in diameter and 2.5–3.8 cm deep. Spawning may actually take place out of both pit and territory. Spawning territories typically situated adjacent to bank or up to 3 m from shore and usually associated with submerged logs or rocks. Density of territories may approach 100 per 0.9 square meters area.[26,29,32,48]

Time: Morning (0800 hours)[11] and afternoon[13] (1400–1840 hours), with activity diminishing as darkness approaches.[26]

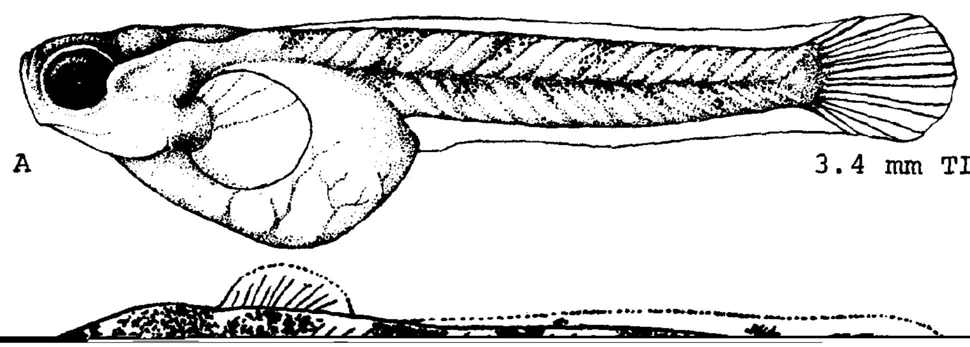
Temperature: 22.8[46]–28.9 C.[26]

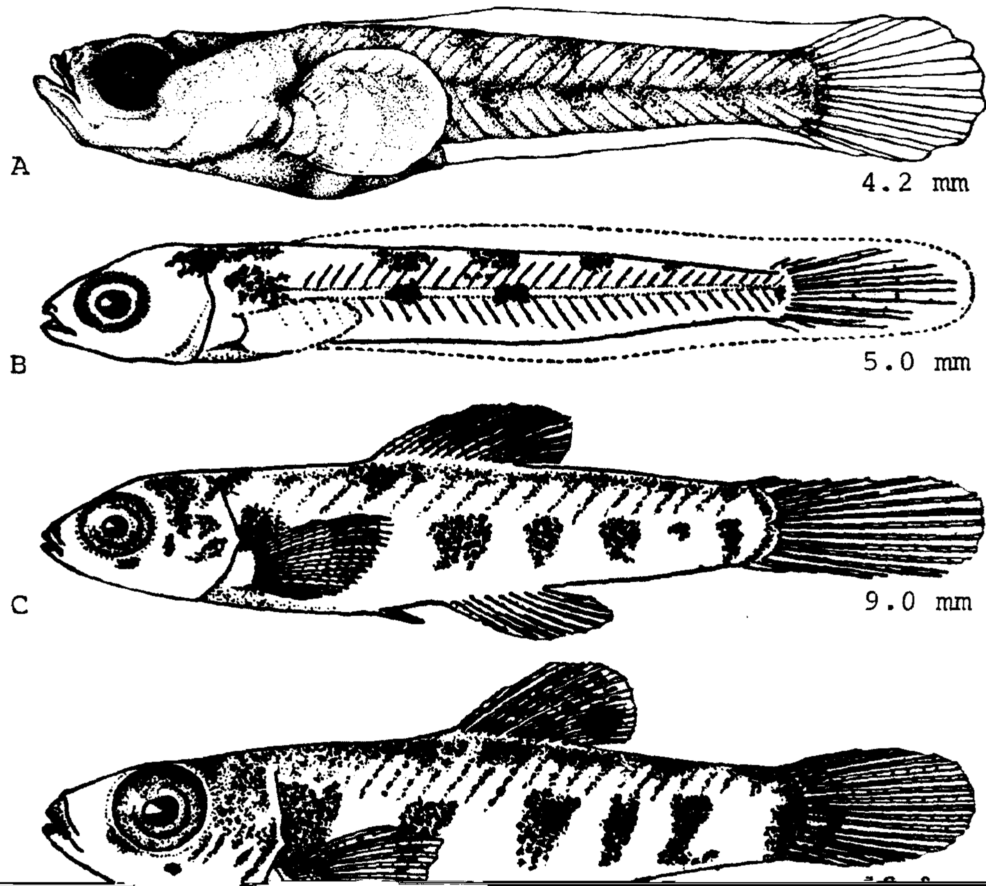
Salinity: 0.08–63.1 ppt, with sudden drops in salinity apparently initiating spawning activity.[65]

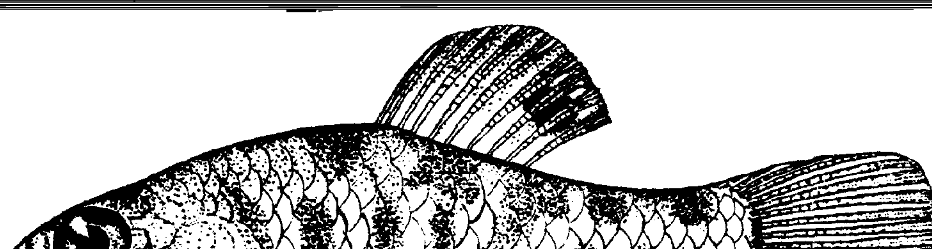
Frequency: A single female may spawn a number of times during a single season at intervals of 1[26]–7 days,[46] (although other eggs were probably eaten by adult fishes, NRF).

Unfertilized eggs: Micropyle single, a cone-shaped funnel without clearly defined edges and which indents slightly into the yolk; attachment structures or adhesive filaments in vicinity of micropyle enlarged and arranged in star-shaped configuration.[13,31]

Fertilized eggs: Spherical;[5,31,32] diameter 1.0[46]–1.73 mm[13] (reported averages ca. 1.3[51] and ca. 1.5 mm); colorless, nearly colorless,[25,27] or yellowish;[31,32,33,61] clear,[13,46] the transparency increasing after differentiation of blastodisc; egg membrane thick, horny,[31] covered with fibrous sticky coat[27] comprised of evenly distributed microscopic filaments attached by club-like structures;[1] yolk with one large oil globule and several groups of much smaller oil globules;[5,33,38] perivitelline space narrow (JDH).




A
4.2 mm
B
5.0 mm
C
9.0 mm



EGG DEVELOPMENT

Development at unspecified temperature:

- Blastodisc stage—blastodisc of nearly uniform thickness throughout central area, thinning out abruptly near periphery.
- About 1 hour, 30 minutes—first cleavage.
- About 2 hours—2nd cleavage, blastomeres approximately equal in size and symmetry.
- By time of 4th cleavage—arrangement of blastomeres distinctly irregular.
- At less than 24 hours—blastoderm completely around yolk; blastopore closed; embryo less than 1/2 around yolk, short, thick, non-segmented, non-pigmented and somewhat irregular in outline.
- Soon after closure of blastopore—large melanophores sparsely scattered over surface of embryo and throughout extra-embryonic blastoderm.
- Somewhat later—yellow chromatophores appear on embryo and in extra-embryonic blastoderm.

a row of orange and black chromatophores (predominantly black) along ventral edge of notochord; a series of more or less evenly spaced orange spots along dorsolateral surface of body; large stellate leucophores on body, caudal fin (where they are the dominant pigment), the underside of the head, and in dense clumps at pectoral bases; bright yellow chromatophores on ventral aspects of head and in thoracic region.[67]

Hatchlings otherwise described as yellowish throughout; posterior half of body with lighter and darker vertical bars; and with chromatophores scattered over head and anterior part of body. At 5.0 mm vertical bars somewhat more developed.[31,38] Some specimens of unspecified length, however, "almost entirely unmarked."[14]

LARVAE

Specimens described, 7.0[46]–9.0 mm.[31]

At 9.0 mm body relatively slender, dorsum not conspicuously elevated. Dorsal, anal, caudal, and pectorals fully

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Fundulus confluentus Goode and Bean, Marsh killifish

ADULTS

D. 8 [39]–13,[27] mode 11; [4] A. 7 [15]–12; C. (branched rays) 13–20; [27] P. 13 [27]–18; [26] V. 6; [23] lateral line scales 30 [27]–42; [39] oblique scale rows between upper angle of gill opening and dorsal origin 18–19,[16] from anus forward to middle of back 15, from nape to dorsal origin 18 [23]–22; scales around caudal peduncle 15–18; mandibular pores 6–10; gill rakers 4–9; [27] branchiostegals, possibly 5.[22]

Proportions as times in SL: Depth 3.5 [27]–5.5; [39] head 2.8–3.6; caudal peduncle depth 6.0–8.2; caudal length 3.6–5.0; dorsal length 3.2–5.7; anal length 3.6–5.6; pectoral length 5.0–6.5; dorsal origin to caudal base 2.5–3.2.[27] Proportions as times in HL: Eye 3.0–4.0,[39] snout 3.3–3.5.[33]

Body rather slender, compressed; caudal peduncle strongly compressed; head depressed,[16] small, narrow;[23]

males dark to tip [38]). Pectorals orange, slightly dusky,[23] and with melanophores along rays.[27] Pelvics plain orange.[23]

Females brown or olive above,[16,27] the back sometimes with small dark blotches.[23] Sides with vertical bars, spots, spots and bars,[27] or *horizontal streaks*; *vertical bars* entirely lacking in some populations.[34] Ventral surfaces pale,[23] dusky white, yellowish,[27] or slightly greenish. Head with irregular sprinkling of black dots.[16] Dorsal fin dusky,[23] milky white, yellow,[27] or golden dusky; [16] dorsal ocellus well-developed, reduced, or absent; [27] when present, ocellus bordered, at least above and below, with "pale" [8] or white; [23] sometimes noticeably elongate.[16] Anal milky white, yellow,[27] or wine colored [16] and with some melanophores.[27] Caudal plain dusky, milky white, yellow,[27] or dusky golden.[16] Pectorals transparent,[27] dusky

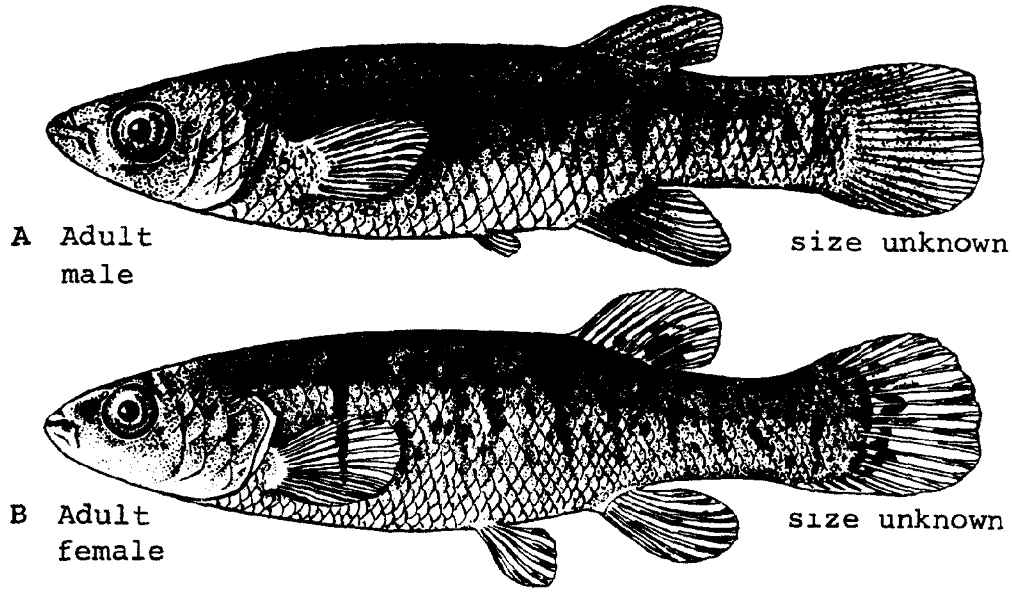


Fig. 82. *Fundulus confluentus*, Marsh killifish. A. Adult male, size unknown. B. Adult female, size unknown. *(A, B, Hildebrand, S. F., and W. C. Schroeder, 1928: figs. 74–75.)*

Larvae—no information.

Juveniles—maximum recorded salinity, 3.7 ppt; maximum recorded temperature, 28.3 C.[42] Specimens 19.0 mm long from tidal streams in Florida.[11]

SPAWNING

Location: In nature among "plants"[30] (including algae masses[35]) in both fresh and brackish water in rainfilled swales[7,27] and pools, as well as the fluctuating margin of brackish tidal water.[2] Under laboratory conditions directly over bare substrate of sand (which may be preferred spawning site for subspecies *F. confluentus confluentus*),[37,44] over clumps of spanish moss,[39] randomly on submerged spawning mops,[37] and at or near surface near corks of floating spawning mops.[34] Drewry listed spawning sites of *F. confluentus pulvereus* in decreasing order of preference (under laboratory conditions) as finely divided plant material of any sort, vertical or overhanging solid surfaces, and loose sand or gravel.[38]

Season: In Florida ripe individuals reported in all months, and apparently continuous at least in Everglades and Florida Keys.[7,10,27,32] In Texas ripe males year round, ripe females recorded in all months but November and December; spawning period 10, or possibly 12, months.[38] Because of possible misidentifications, reports of spawning in April and May in Chesapeake Bay and from April to October at Beaufort, North Carolina[16] are questioned (JDH).

Temperature: Spawned in aquaria in which temperatures varied from 23.3–27.2 C.[37]

Fecundity: 34–61 ripe ova.[32]

EGGS

Location: Demersal (JDH), possibly attached to plants[30] or algae masses;[35] under experimental conditions buried in substrate, or attached randomly to spawning mops from bottom[37,44] to near surface;[34] sometimes stranded out of water on ground surface among plant litter or in moist matted algae.[2,7]

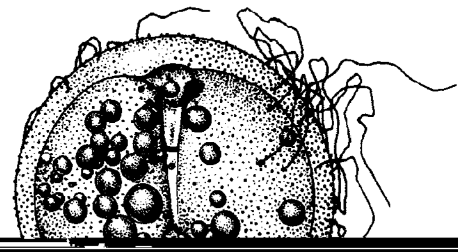
Ripe ovarian eggs: Yellowish, diameter 0.8 to ca. 1.5 mm.[10,32,35,40]

Fertilized eggs: Diameter 1.6–1.8 mm;[35] usually (JDH), but not always, round;[30] chorion with both attachment filaments and "chorionic bristles"[44] or "minute punctae[35] (scanning electron micrographs of these structures show them as small, spherical nodules[37]); yolk with 10–15 oil globules.[35]

EGG DEVELOPMENT

Embryos "well developed" in 5 days at unspecified temperature.[30]

Incubation: Variously stated as 10–14 days "with the aid of some microorganism culture" to assist with hatching; [30] "up to 28 days"; [35] 3–4 weeks in the subspecies *pulvereus*.[34,35] At 28.2–29.5 C, 11–17 days (GED). When developed out of water, hatching may be delayed for up to 95 days; such eggs hatch in 15–30 minutes after immersion in tap water.[2,7]



LARVAE

Undescribed, but "young" from eggs reared out of water hatch without visible yolk, and at sizes equal to individuals from water-hatched eggs 2 to 4 weeks old.[2,7]

JUVENILES

Minimum size, unknown.

Pigmentation: In "young" of 30 mm or less the color is uniformly that of the adult female; [16] this is especially true of the basal melanophore layer of *pulvereus* populations; [38] juvenile males may have a dorsal ocellus.[27]

AGE AND SIZE AT MATURITY

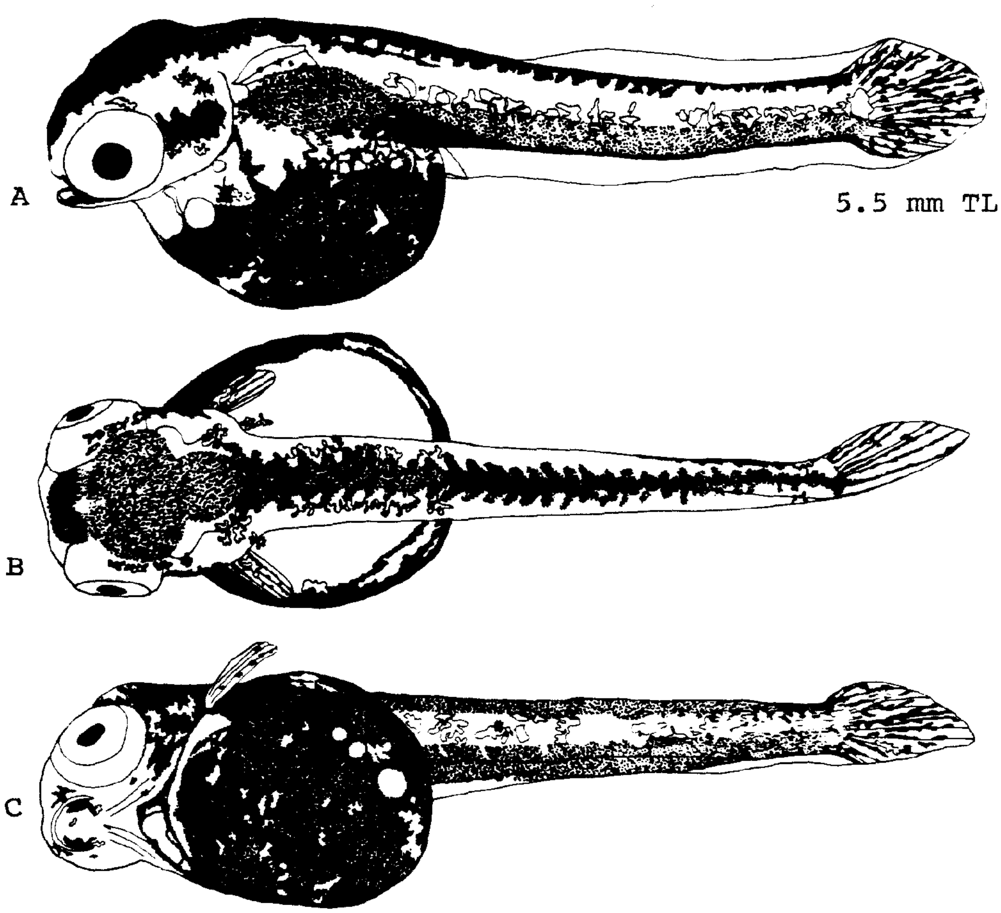


Fig. 84. *Fundulus confluentus,* Marsh killifish. A. Yolk-sac larva, 5.5 mm TL. B. Dorsal view of A. C. Ventrolateral view of A. (*A-C, Original drawings, Linda L. Hudson.*)

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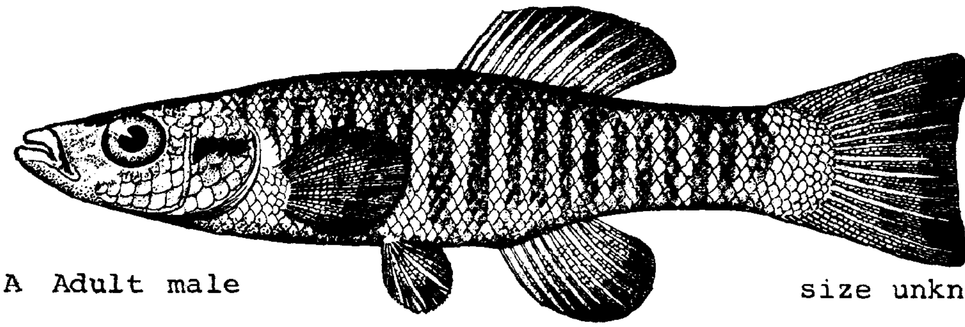
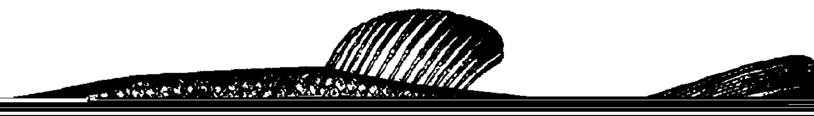
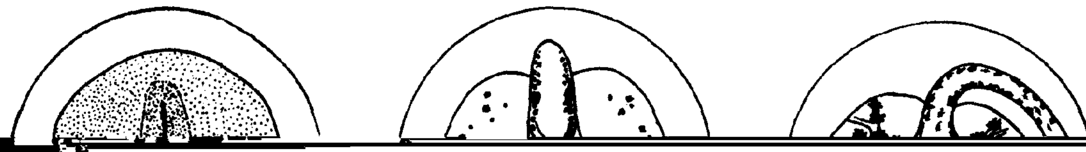
Fundulus diaphanus (Lesueur), Banded killifish

[redacted]



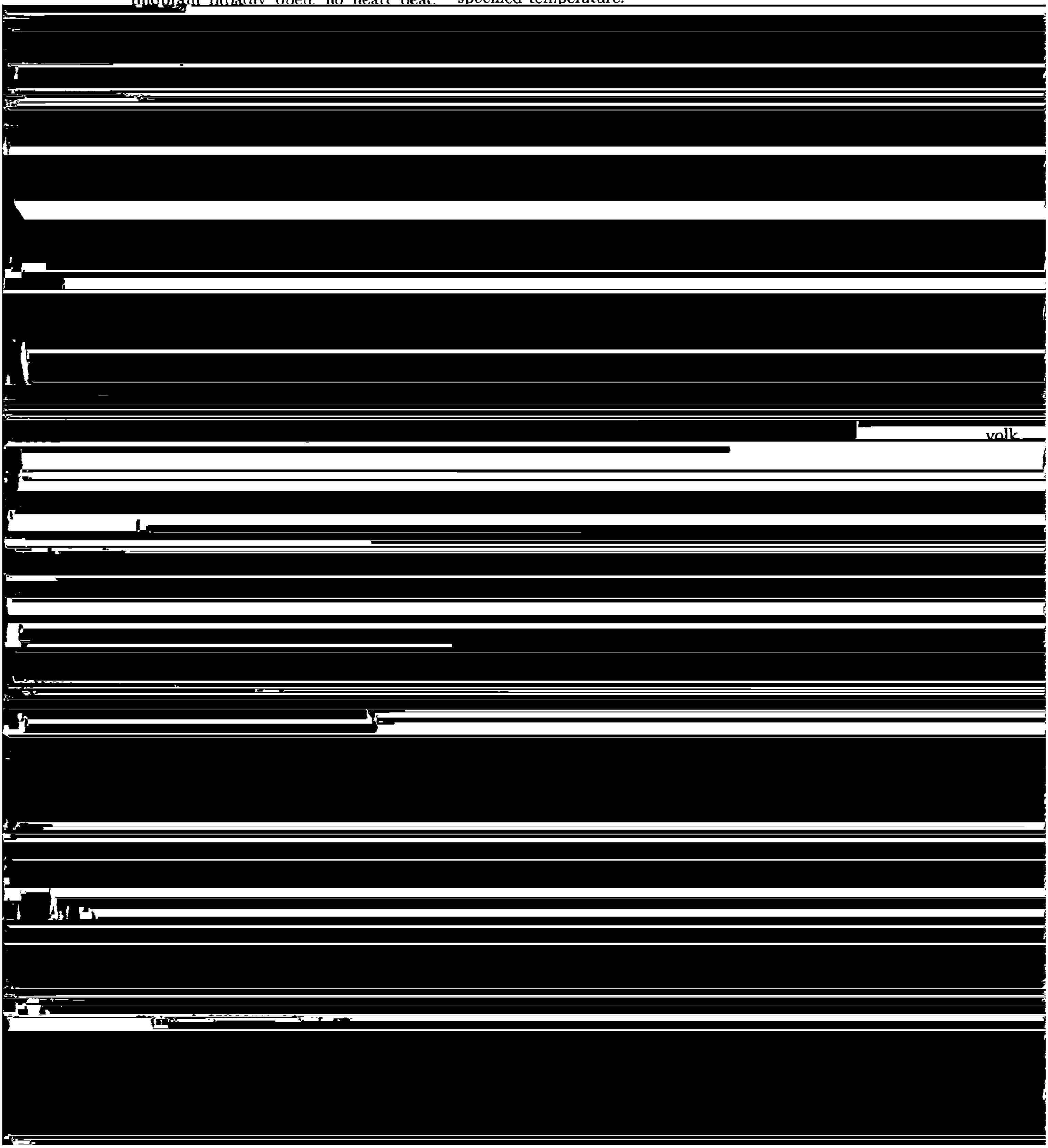
A Adult male size unknown





20 hours—blastoderm with germ ring faintly defined, embryonic shield barely visible.
48 hours—germ ring halfway around yolk, embryonic axis well defined, no neural tube.
72 hours—blastopore closed, embryo with short tail, midbrain broadly open, no heart beat.
216 hours—embryo light-colored; tail long, slender.
312–360 hours (13–15 days)—hatching.[29]

Incubation: 11–12 days at 22.0–26.5 C; [38] 16–18 days at 12–14 C; [67] newly laid eggs hatched in 9 days at unspecified temperature.[78]



Pigmentation: At 5.3 mm (described from life) dorsal aspects of head dark; an indefinite row of dark pigment dorsally along body and a similar row along dorsal edge of notochord; ventrally dark pigment sparse, limited to series of small dots along mid-ventral line, no pigment immediately below notochord; dark pigment along developing caudal rays and on yolk sac; no pigment in developing pectoral fins; very large stellate white chromatophores on head and body and at bases of pectoral fins; smaller white chromatophores on yolk sac; few orange chromatophores on ventral aspects of body and yolk. In preserved specimens of this size no pigment immediately below notochord or in pectorals, absent or poorly developed above notochord.[76] At 7.1 mm, chromatophores over entire body, especially on top of head and in an irregular series on dorsal and ventral ridges; lateral chromatophores stellate, delicate, more numerous along lateral line and myosepta; heavy pigment on isthmus, continuing along mid-ventral line to stomach; few chromatophores on pectorals and along caudal rays.[32] Pigment along developing caudal rays variable: apparently lacking in some populations;[72] well-developed in others.[76]

LARVAE

Size range described, 6.0[67]–12.3 mm.[32]

Preanal myomeres 10, postanal myomeres 20–22.[32]

Proportions expressed as times in TL at 12.3 mm: Snout-vent length 2.1, head length 3.6, greatest depth 5.13.[32]

At 12.3 mm mouth more superior than in earlier stages, finfold nearly obliterated; pelvics first evident.[32]

Pigmentation: At 12.3 mm body covered with stellate chromatophores except beneath stomach; chromatophores along rays of dorsal, anal, pectorals, and caudal.[32]

JUVENILES

Specimens described, up to ca. 50 mm.[27,45,51]

Pigmentation: Young or immature with dark vertical bars[7,11,59,62] on pale olivaceous background. Differentiation of adult pattern occurs at ca. 50 mm[27,45,51] although specimens below this size may be mature.[69] With a 14-hour photoperiod and a temperature of 26.1 C, sexes can be distinguished 87 days after hatching.[78]

AGE AND SIZE AT MATURITY

During third summer,[38] although specimens 70 mm and 6 1/2 months have been reported approaching maturity;[7] ca. 38 mm in subspecies *menona*, 52.5 mm in *diaphanus diaphanus*.[69]

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Fundulus heteroclitus (Linnaeus), Mummichog

ADULTS

D. 10 [156]–14; [38] A. 9 [156]–12; [31] C. 17–22; P. 16 [156]–20; [160] V. 6 [50]–7; [156] scales, lateral rows 31 [43]–39,[8] predorsal 18–22, between dorsal origin and anal origin 14–16; [45] in transverse series 13–15; [53] gill rakers 7 [141]–12; branchiostegal rays usually 5,5 sometimes 5,4 4,5 5,6, or 6,6; [50,83,156] vertebrae 32–35 [156] (decreasing in number with increasing developmental temperature [110]); precaudal vertebrae 14–15; caudal vertebrae 19–20; [50] 6 paired canals on head, each with 2–7 external pores; [30] total mandibular pores, 8; [19,88] preopercular pores, 7.[120]

Proportions expressed as times in SL: Head length 2.8–3.7,[19] average depth 3.2–4.0,[21] depth at pectoral base 4.4.[83] Proportions as percent TL, greatest depth 15.8–20.0, head length 20.6–25.0; as percent HL, eye 21.6–28.3.[141]

Body robust,[8] short, deep; [18] back elevated; [8] caudal peduncle strongly compressed.[31] Head short, broad, depressed; [18,31,104] mouth small, terminal, mostly transverse; [31] lower jaw projecting beyond upper; [93] premaxillary protractile.[156] Teeth pointed, in villiform bands, the outer ones enlarged.[31] Dorsal fin origin somewhat anterior to anal fin origin; [31,93] dorsal and anal fins of male larger than those of female; [23,68] pelvic fins usually equidistant from tip of snout and caudal base; [21] caudal fin broadly rounded.[31,93] Males with contact organs on side of head, on body below and behind dorsal,[132] and, possibly (identity questioned, JDH), on anal rays, during and within eight weeks after spawning.[36,76] External oviducts varying seasonally from 45–65% of anterior margin of anal in southern New England populations.[83]

Pigmentation: Typically olivaceous to dark green above, pale to yellow-orange below.[93] Color highly variable,[17,87,89] depending on external stimuli,[75,97,101,121] and assuming tints of pink, yellow, green, or blue.[118] Scales of both sexes sometimes with white spots [43] arranged either in short vertical bars and scattered at random on body or in longitudinal or diagonal stripes.[138] Males dark green [17,18,53] or blue-green above,[131] yellow below; sides with narrow silvery white bars, between which are numerous small whitish or yellowish spots; head yellow below; [53] dorsal with or without dark ocellus on posterior rays,[43,53,131] dorsal ocellus present year round in some populations,[43] present seasonally in others,[109] otherwise dorsal fin dusky or spotted; anal and caudal fins dusky or spotted; pelvic fins dusky, edged with yellow-gold.[23,131] Body of spawning males with extensive bluish or orange reflections; [68,112] blue-black above, yellow or greenish yellow below; [131] sides with ca. 15 narrow silvery vertical bars and numerous white or yellow spots extending

culum dusky above, golden below; chin olive; anal and pelvic fins golden.[31] Females brownish green to nearly plain olive above,[8,131] lighter below; [53] fins plain tan,[131] the vertical ones sometimes with greenish tinge. Smaller females with 13–15 dark crossbars narrower than interspaces.[31] Spawning females very pale.[144] Peritoneum of both sexes almost uniformly black.[141]

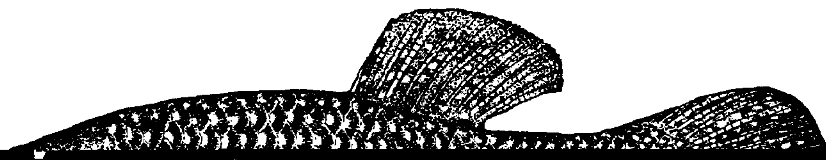
Maximum length: Largest specimen from Chesapeake Bay region 122 mm,[162] with females slightly larger than males.[124]

DISTRIBUTION AND ECOLOGY

Range: Newfoundland [9] and Nova Scotia [40] to Mantanzas Inlet in northeastern Florida; [2,42] introduced in Ohio drainage of western Pennsylvania.[126] (Records from Labrador [41,127] are apparently in error.[9])

Area distribution: Coastal waters of New Jersey,[6,135] Delaware,[7] Maryland,[5] and Virginia; [133,134] north to Havre de Grace in Chesapeake Bay.[31]

Habitat and movements: Adults—a schooling species [5,142] found in fresh,[80,85,97,98] tidal fresh,[77,108] brackish,[19,27,31,40,92] and salt water,[31,40,125] and capable of withstanding abrupt salinity changes.[103] Recorded from nontidal portions of large rivers; [100] freshwater streams,[93] and creeks; [1] lakes; [100,157] salt marshes; [1,7,71,161] barrier beach ponds; [55] tidal streams,[86] creeks, and ditches; [161] near tributary inlets in bays; [12,27] in shallow brackish coves; [31] near docks; along beaches; [5,14] and in ocean surf.[86] Frequently associated with vegetation such as eelgrass, *Salicornia*, and *Spartina*.[27,35,54,87,112] Apparently ubiquitous in some areas,[22] but preferring muddy water [53,144,159] and muddy bottom elsewhere.[31] Capable of moving overland or burrowing in mud when stranded in small ponds above tide,[87,161] and can remain out of water for at least four hours without apparent injury.[111] Sometimes found in extremely foul, polluted water.[33,44,90,105,112] Migratory,[68] moving to marshes and freshwater creeks in late March (at water temperature of 15 C), with peak of migration occurring in mid-April. Run in and out with tide during summer months until temperature of pools reaches ca. 24 C (during August), then cease running for over two weeks, reappearing in early September and continuing to run until temperature is down to 10 C.[1,17,35,71,91,144] May retire to deep mud holes near mouths of creeks in winter, but also hibernate inshore, burrowing 15–20 cm in mud in salt marsh pools and sheltered lagoons.[1,17,87,111,112] Maximum distance from shore, seldom more than 90 m; maximum depth, seldom deeper than "a couple of fathoms"; [87] salinity range (natural), 0.0 [80,85,157]–41.0 ppt; [159] experimental, up to 106.0–120.3 ppt.[158] Minimum re-



SPAWNING

Location: Salt, brackish, and freshwater[13,71,112,134] in ponds,[23,161] shallow pools,[62] rivers,[134] and "pure sea water."[65] Spawning takes place in shadowed areas[31] over shallows above gravelly[135,161] or hard bottoms having sparse[71] to dense[107] vegetation; also among emergent vegetation in intertidal zone,[78,135] among *Spartina* roots,[144] and sometimes so close to shore that eggs may be washed ashore and left above water line by receding tide.[78,135] Observed spawning in large numbers in pools not over 9 square m in area of more than a few centimeters deep.[62] Individuals depositing nearly afilamentous eggs spawn over tidal flats inside empty shells of the ribbed mussel, *Modiolus demissus*.[143]

Season: In North Carolina early May to late August;[54] in Virginia (reduced filament population), eggs observed May 3 to September 3;[143] in Chesapeake Bay, April to August;[31,131] in Delaware Bay, May 4 through mid-August with several peaks at or near new moon high tide;[124] in New Jersey, April to late August, peak late May;[1,17] in New York, males with breeding colors April 27;[71] in Rhode Island, June to July;[27] in Connecticut, May to July;[73,123] in Massachusetts, nuptial colors of males, April through August,[109] spawning mid-May through early August,[26,63,79,95,96,128,129] peak June and July;[54] in Gulf of Maine, June to early August.[144] Spawning colors may begin to develop in early February in aquaria,[119] and may be evident until October (by implication, JDH) in natural populations.[109] One female may produce several groups of eggs during a single spawning season.[31,124]

Time: During daylight hours (by implication, JDH),[23] mid-day.[107,144]

Temperature: 16.5[159]–25.0 C.[107]

Fecundity: 460–800 mature ova;[31,47,61,124,131] one female from a population having reduced egg filaments deposited

[redacted]

1–718 eggs in various stages of development). Eggs in shells sometimes exposed and dry, yet hatch when submerged.[143] Under experimental conditions normally filamented eggs placed randomly on spawning mops in nonflowing water,[155] reduced filament eggs preferentially placed against nylon screen in flowing water.[147]

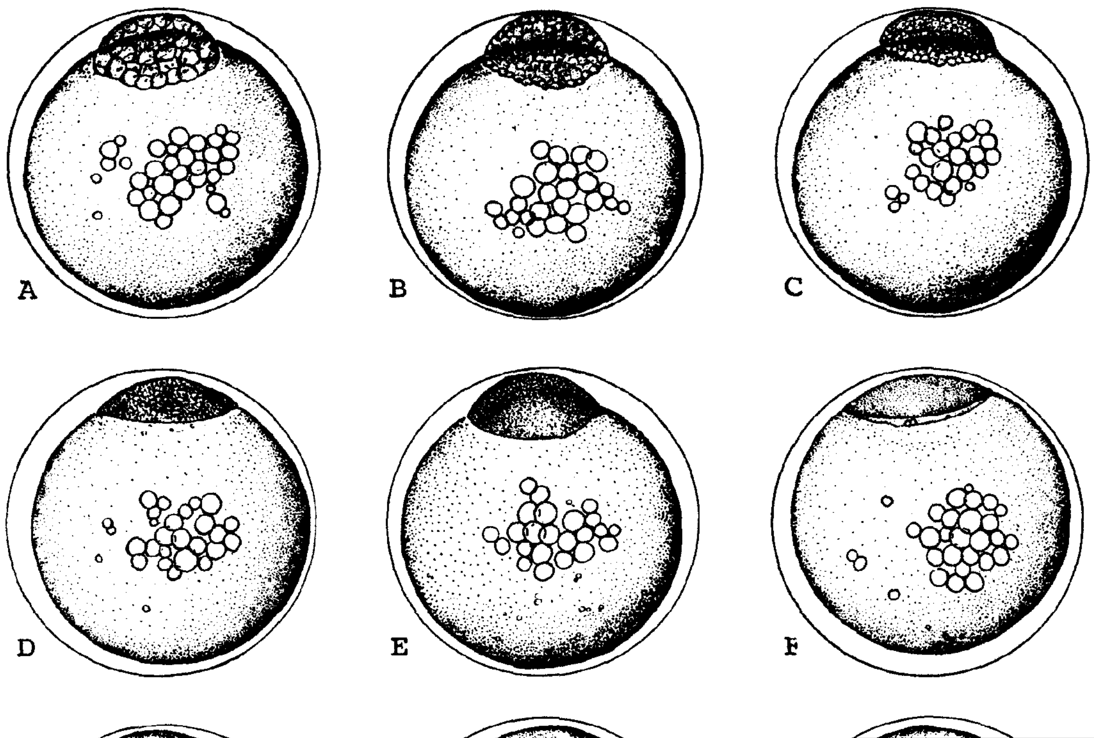
Immature ovarian eggs: At 0.16 mm diameter filaments visible as hyaline dots; at 0.4 mm filaments longer than diameter of egg in one northern population.[64]

Mature ovarian eggs: 1.2–2.0 mm diameter, spherical, translucent, and with small oil globules;[124] filaments present on chorion in some populations, absent or nearly so in others.[54]

Freshly stripped unfertilized eggs: Diameter ca. 2.0 mm, with eggs from smaller females commonly smaller than those of larger females;[73] pale brown,[135] clear yellow,[73] or slightly opaque;[29] yolk platelets and oil globules aggregated at yolk surface;[47,73] yolk mass contained within a single membrane-bound sac enclosed in a layer of cytoplasm with an external limiting membrane on its surface;[145] filaments, when present, in a loose network over chorion;[64,116] micropyle funnel-shaped,[37,47] located at animal pole;[29,114] egg membrane very glutinous.[23,73]

Fertilized eggs: Spherical,[71] yellowish,[11,87,94] amber[71] or almost colorless, nearly or completely transparent[33,51,117] (a report of opaque eggs[72] is questioned, JDH). Diameter ca. 1.5[11,72]–2.5 mm,[44,114,145] average ca. 2.0 mm.[33,112] When developed in seawater perivitelline space increased as yolk used; in distilled water yolk increases in size and perivitelline space completely obliterated as development proceeds.[73] Oil globules opaque,[11] small,[20] unequal,[72] and numerous[11,20,117] (maximum number reported "more than 50"[144]), characteristic in number and size for eggs derived from a single spawning of a particular female,[29] initially grouped together,[72] but gradually carried over yolk by advancing blastoderm.[20] Chorion heavy, firm,[15,87] and apparently thicker in reduced filament eggs;[82,143]

[redacted]


A
B
C
D
E
F

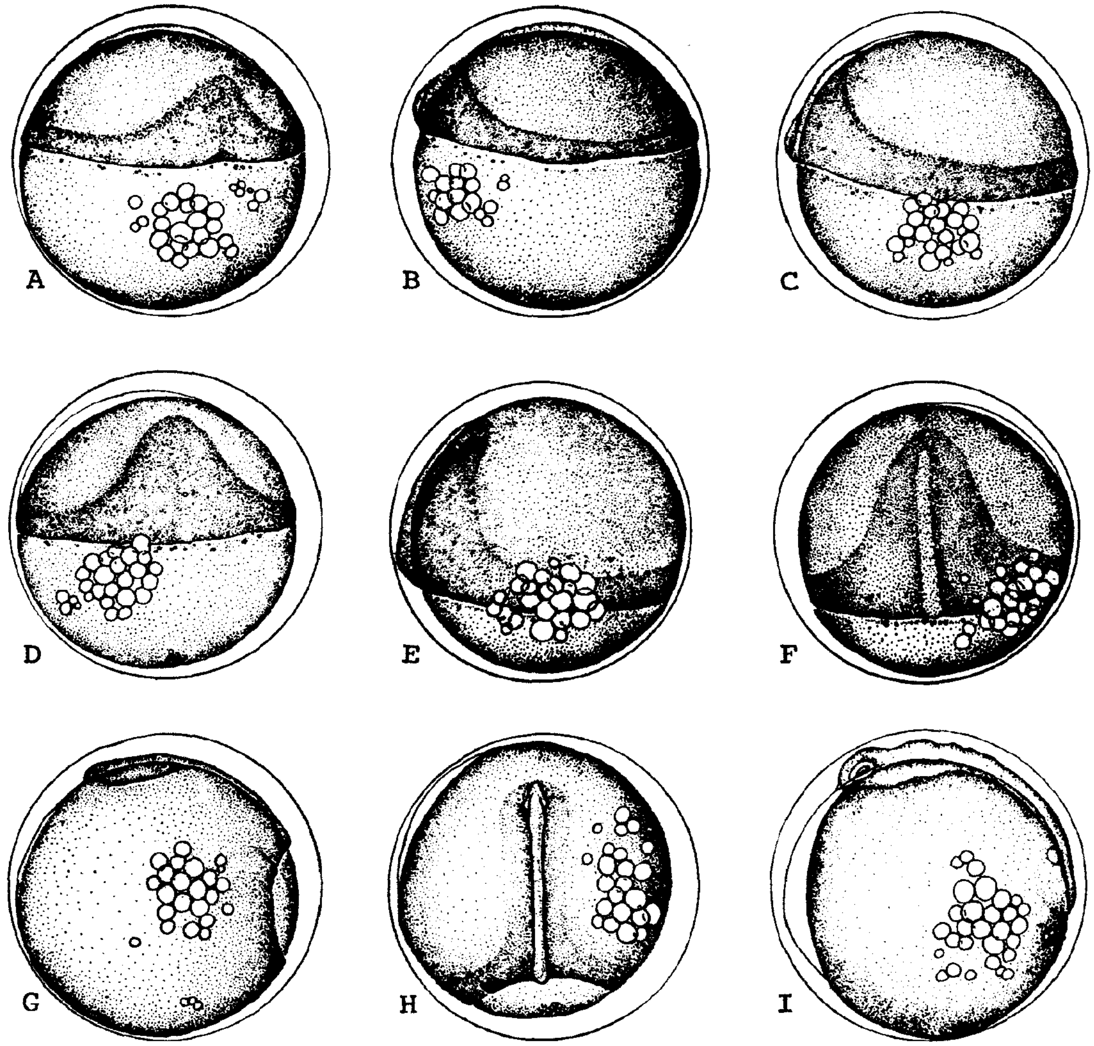


Fig. 91. *Fundulus heteroclitus*, Mummichog. A, B. Embryonic axis increased in length, 30 hours. C, D. Blastoderm over one-half of yolk, 33 hours. E, F. Extra-embryonic ectoderm over three-fourths yolk, 37 hours. G, H. Embryonic keel prominent, optic vesicles rudimentary, blastopore evident as small opening, 40 hours. I. Blastopore closed, main divisions of brain formed, Kupffer's vesicle evident, 46 hours. (*A-I, Armstrong, P. B., and J. S. Child, 1965: figs. 16–20.*)

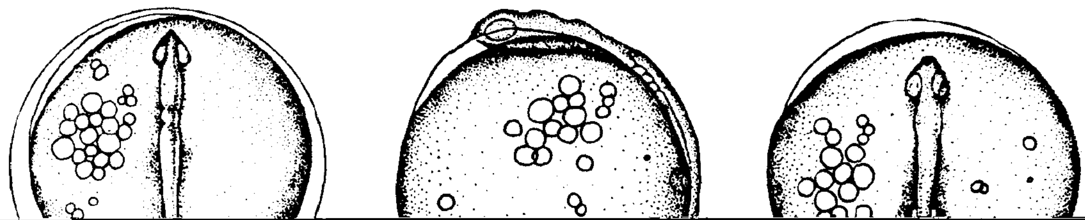
otic vesicles; blood islands of yolk forming a syncitium; circulation not yet established; tail tip rounded, attached; melanophores increased in number, especially on yolk; erythrophores evident under hindbrain and on trunk.

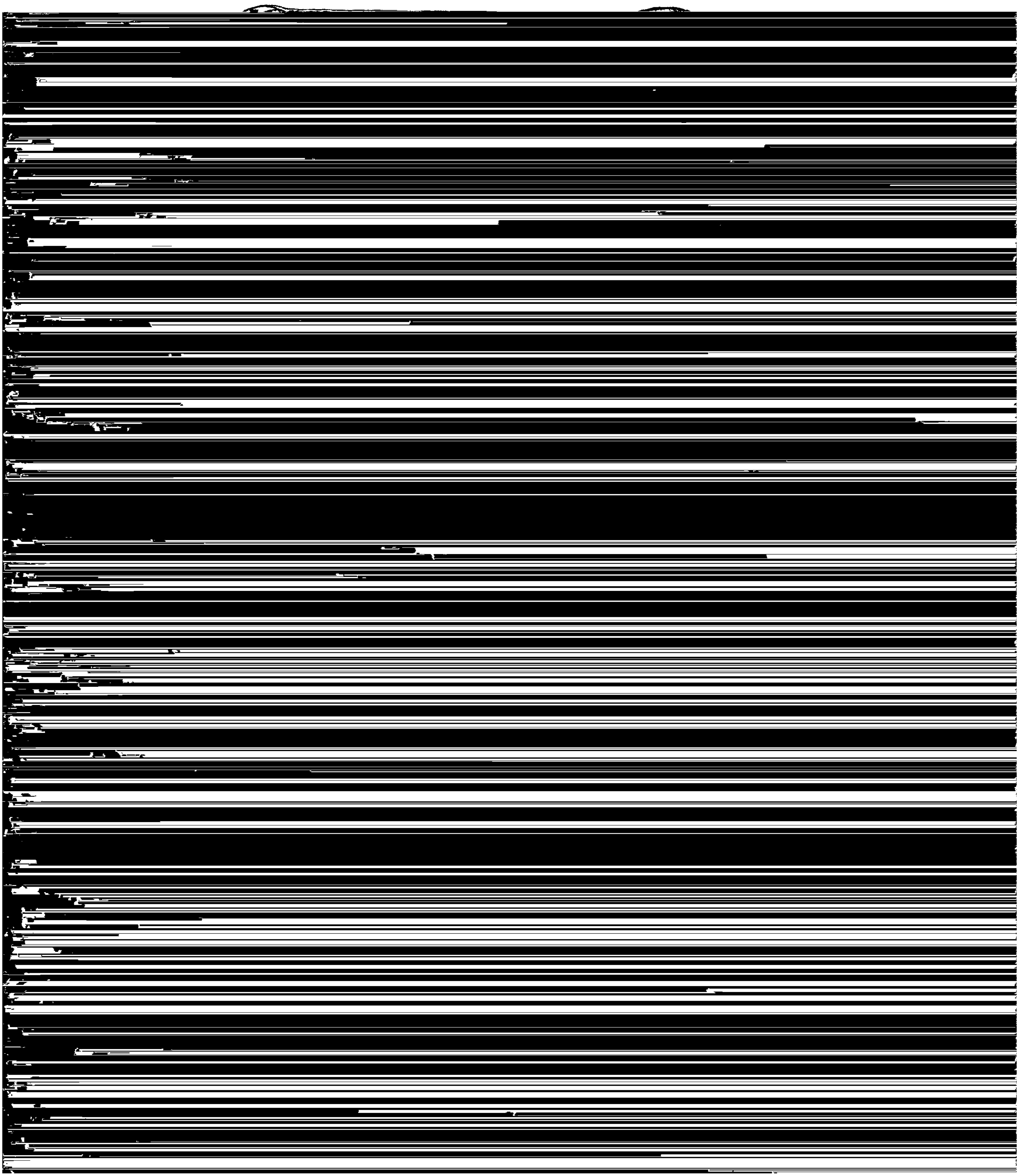
84 hours (Stage 25)—circulation established; contractions of somatic muscles evident; 19 somites present; tail free; melanophores more numerous [redacted]

contracted erythrophores on yolk sac.

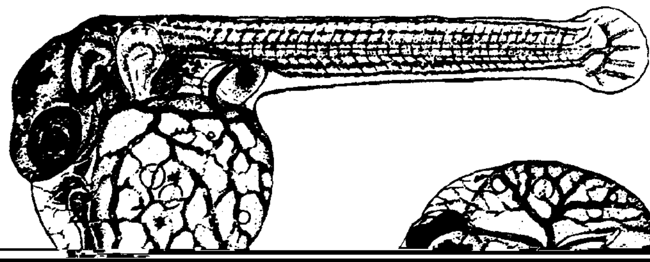
112 hours (Stage 27)—ventricle of heart differentiated; otoliths evident as dense concrete bodies; pronephros functional; urinary bladder not yet formed; yolk melanophores expanded.

128 hours (Stage 28)—developing pectoral fin evident as mass of tissue jutting upward above surface of yolk sac; urinary bladder small, [redacted]





A



under hindbrain and few red chromatophores near head; 72 hours, heart pulsating, no vitelline circulation, few melanophores on yolk and head; 96 hours, vitelline circulation established, body and yolk well-pigmented; 312–336 hours, hatching.[55]

Development at unspecified temperature but as specific stages (the Oppenheimer series): Stage 1, unfertilized egg; stage 2, blastodisc formed; stage 3, 2-cell stage; stage 4, 4-cell stage; stage 5, 8-cell stage; stage 6, 16-cell stage; stage 7, 32-cell stage; stage 8, early high blastula; stage 9, late high blastula; stage 10, flat blastula; stage 11, expanding blastula; stage 12, early gastrula; stage 13, middle gastrula, blastoderm over about one-half of yolk; stage 14, later gastrula; stage 15, closure of blastopore, central nervous system formed, occasionally somites and optic vesicles evident depending on rearing environment; stage 17, optic vesicles hollow, 1–4 somites; stage 18, auditory placodes visible, first indication of extra-embryonic coelom, 4–14 somites; stage 19, neural cavity, lens, olfactory pits, 14–20 somites formed; stage 20, optic lobes formed, ear vesicular, blood islands on yolk, heart pulsating, pericardium differentiating, pectoral buds evident, melanophores on yolk and anterior part of body, 20–25 somites; stage 21, muscular contractions evident, optic lobes formed, ca. 28 somites; stage 22, circulation established, cerebral hemispheres forming, ca. 35 somites; stage 23, otoliths formed, melanophores on pericardium; stage 30, caudal rays visible, lower jaw formed; stage 31, swim bladder evident as diverticulum from gut, eyes and mouth movable; stage 32, hatching.[28,29]

Development at unspecified temperature (the Richards and Porter series): 10 hours, blastodisc lenticular, segmentation cavity formed; 14 hours, embryonic shield just forming; 18 hours, germ ring ca. one-third around yolk; 24 hours, germ ring to equator of yolk, embryonic shield elongated, anlagen of embryonic axis and neural furrows evident; 30 hours, germ ring nearly closed, optic bulbs evident, mesoderm thickened into lateral plates, notochord forming.[16]

Development at unspecified temperature (the Stockard series): ca. 2 hours, 2-cell stage; 18–20 hours, blastoderm flattened; 24 hours, blastoderm one-fourth to one-

erated and the perivitelline space was formed 5 minutes after fertilization.[47]

Moenkhaus noted the following variations in developmental sequences at unspecified temperatures: 2-cell stage, 47 minutes to 2 hours and 20 minutes; 16-cell stage, 2 hours and 15 minutes to 4 hours and 5 minutes; closure of the blastopore, 40 hours and 35 minutes to 86 hours and 30 minutes.[50,61]

Bancroft stated that, at the time of initial heartbeat, melanophores appear on the yolk, the forebrain lacks a lumen, and there are ca. 12 somites.[56]

Gilson described 7-day embryos as having large melanophores close to and above the neural tube and beneath the musculature of the tail, and numerous small melanophores in several distinct series on the tail. The posterior melanophores were strikingly metameric although irregularities were noted.[25]

Shepard concluded that the pigment cells on the yolk sac are not of neural crest origin, but appear to arise from the extra-embryonic germ ring.[70]

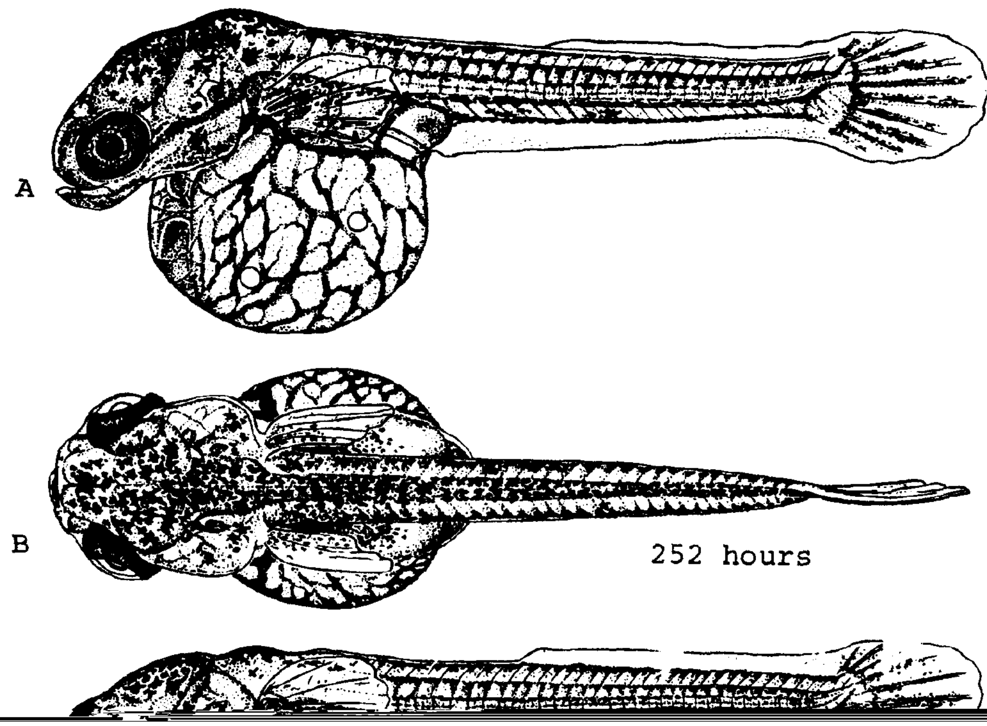
Stockard found that at 5 C, 20 hours were required for development of 2- and 4-cell stages, while at "unusually warm temperature" the germ ring was one-third to one-half over the yolk, the embryonic shield was well-formed, and the embryonic axis was indicated in only 22 hours. In a later series 10–12 somites were formed in 48 hours, the heart was pulsating in 53 hours, and circulation was established in 72 hours.[46]

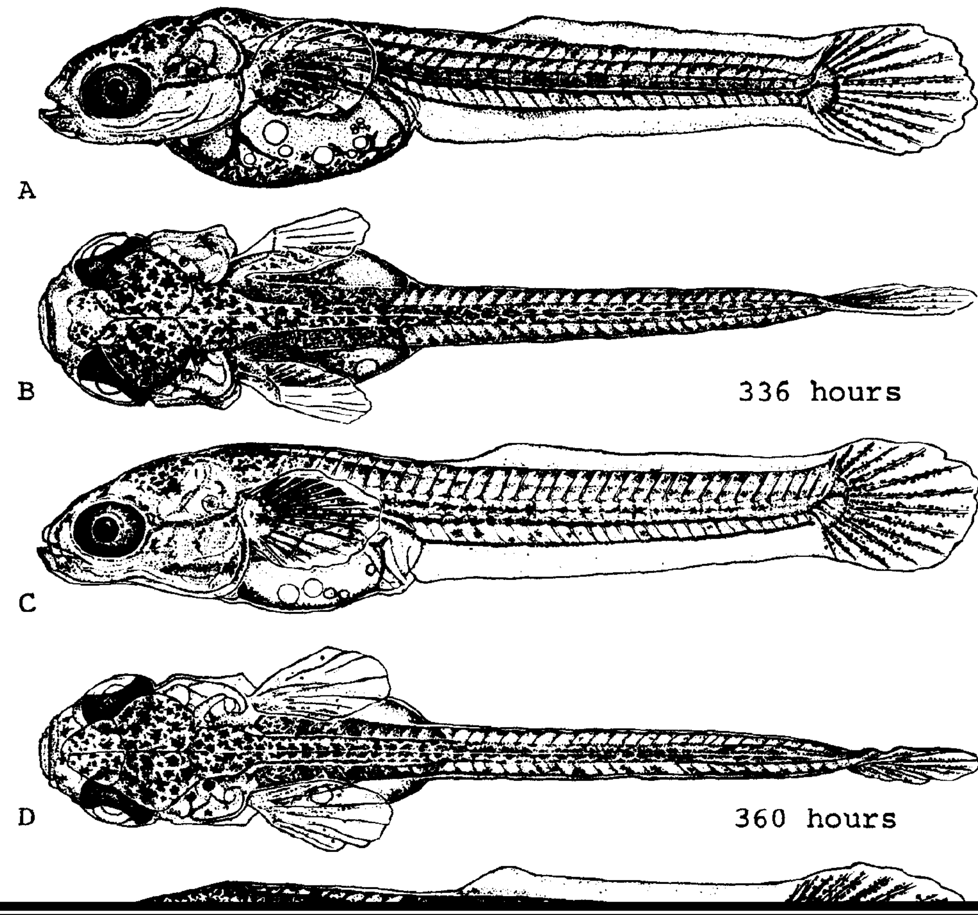
Rogers noted the optic cups, lenses, and optic stalks in embryos 63 hours old which had been reared at 22–26 C. The optic tract was formed in 99 hours.[81]

Bancroft observed a continuous mid-lateral line of red chromatophores in embryos just prior to hatching.[56]

Russell found that melanophores first appear on the head 4 days after fertilization. On the sixth day melanophores of the yolk sac migrate to the yolk-sac vessels. Advanced embryos usually have 8–18 (average 13) melanophores on the dorsal surface.[96]

Milkman found that, just prior to hatching, the mouth


A
B
252 hours


A
B
336 hours
C
D
360 hours

Temperature tolerances: 12 [117]–30 C.[140] During early development eggs are killed or develop abnormally when subjected to reduced temperatures (0 C to possibly 10 C). Advanced embryos can survive temperatures of 0–2 C for rather prolonged periods.[49,60]

Salinity tolerances: Eggs will develop in distilled water, seawater, or "concentrated sea water"; [106] those hatched in freshwater are typically 2–5 days behind those in seawater,[24] although at 60 ppt onset of hatching is retarded.[140]

Note: Eggs can be kept under "complete vacuum" for 4 days.[74]

YOLK-SAC LARVAE

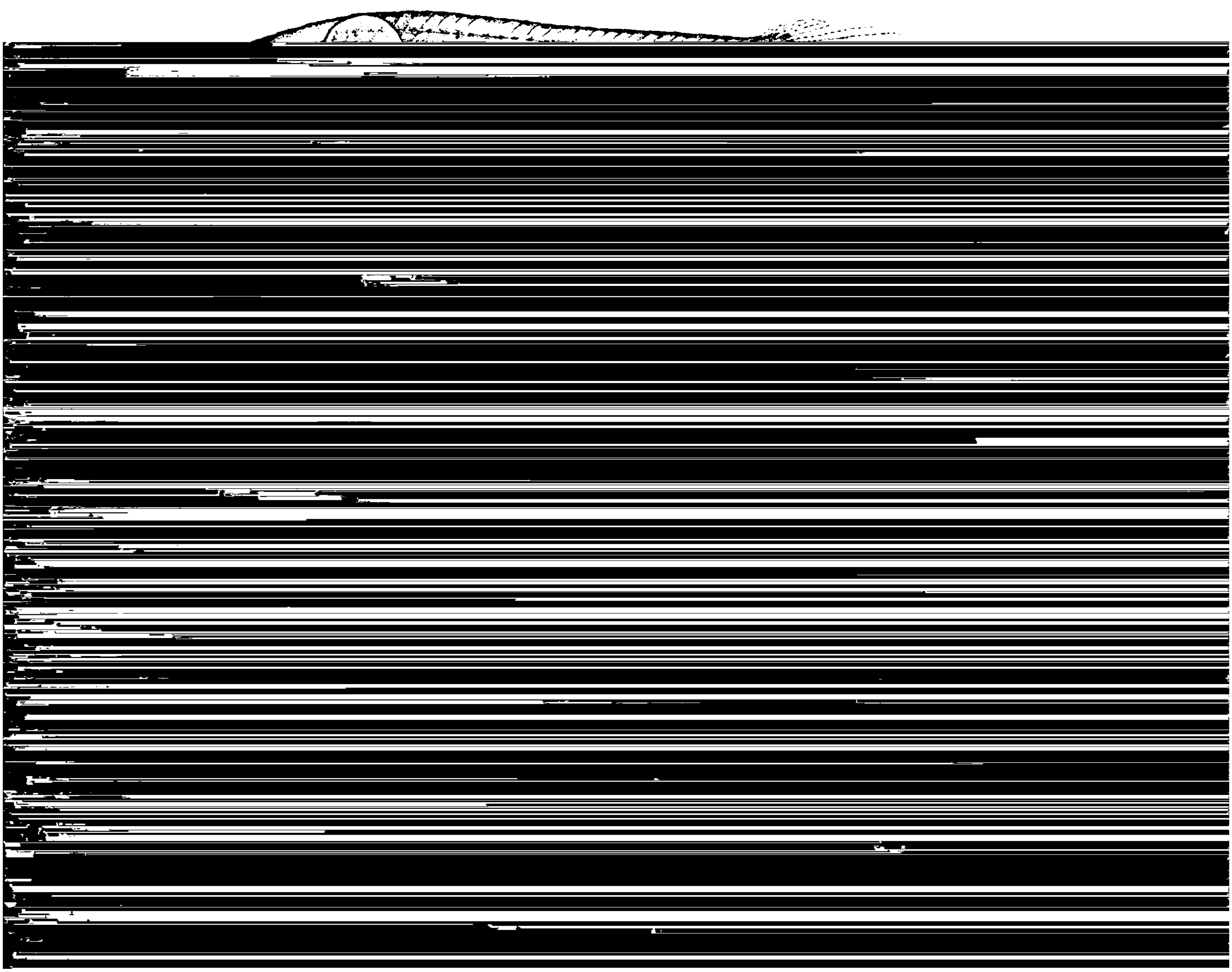
Hatching length 4.0 mm or less [102,154] to 7.7 mm [156] (larger specimens may hatch as larvae [71,87,112]). Average hatching length, 5.0 mm.[148] In one set of experiments hatching length varied 5.13±0.06 to 6.85±0.04 mm.[140]

Yolk retained for 24 [66] to 156 hours after hatching [146] or to length of 7.0–10.0 mm.[153]

Myomeres 33 [154]–ca. 35,[117] also reported as 9 + 24.[154]

Head initially flexed over yolk, straightened by end of stage. Opercular margins well defined at hatching. Yolk sac variable, large and round at hatching [73] or greatly reduced; [26,117] oil globules retained throughout stage.[73] Skeleton well ossified,[110] urostyle oblique,[73] pectoral rays evident [33] at hatching. Typical lateral line cupulae present one day after hatching.[122] Gas bladder considerably enlarged as stage progresses.[29] Origin of dorsal finfold at midpoint of TL at beginning of stage, somewhat more forward at end of stage; [73] origin of anal finfold about one-third distance from tip of snout to tip of tail.[144]

Pigmentation: At hatching a series of melanophores on each side of mid-dorsal and mid-ventral lines, typically restricted to the somites; a continuous mid-lateral series of red chromatophores and 0–2 large mid-lateral melanophores [25,56] (although in some populations the mid-lateral



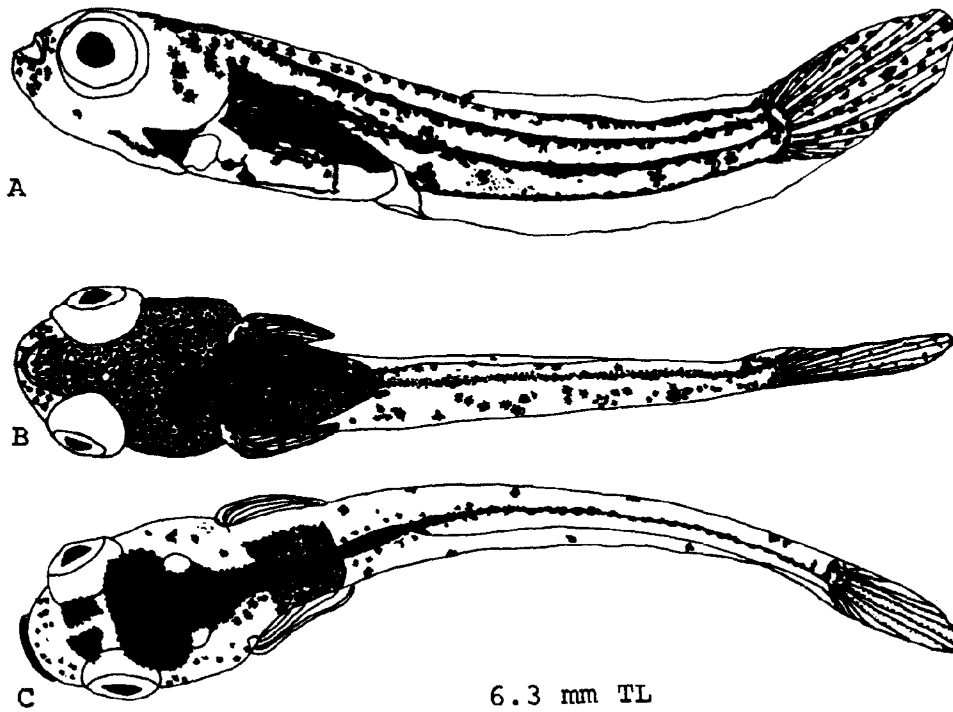


Fig. 99. *Fundulus heteroclitus,* Mummichog. A, B, C. Yolk-sac larva in life, 6.3 mm TL, lateral, ventral and dorsal views. (*A-C, Original drawings, Linda L. Hudson.*)

series is not this well-developed [144]); melanophores of yolk sac densely aggregated over vitelline vessels. At one day 1–26 (average 8) melanophores in mid-lateral series.[25,56] Gas bladder pigmented before complete absorption of yolk.[66] At 6.3 mm (in life) dark pigment on head, in relatively thin bands on dorsal and ventral surfaces of body, above and below notochord, and along developing caudal and pectoral rays; a series of widely spaced stellate white chromatophores on ventrolateral aspects of body just over ventral edge of notochord; a cluster of large white chromatophores on caudal base; white pigment in throat region and in dense masses on bases of pectoral fins; scattered orange chromatophores on yolk sac and yellow pigment in small area on ventral part of body just behind yolk.[154] A 7.3 mm specimen has a distinct triangle of chromatophores on head behind eye and stellate chromatophores scattered over dorsum.[33] In specimens with yolk nearly absorbed, yolk chromatophores arranged in a compact mass, especially in region of falciform ligament of liver and Cuvierian ducts, compact mass of pigment cells over pericardium, along aorta to branchial arteries, and surrounding ventral vein to cloaca.[25]

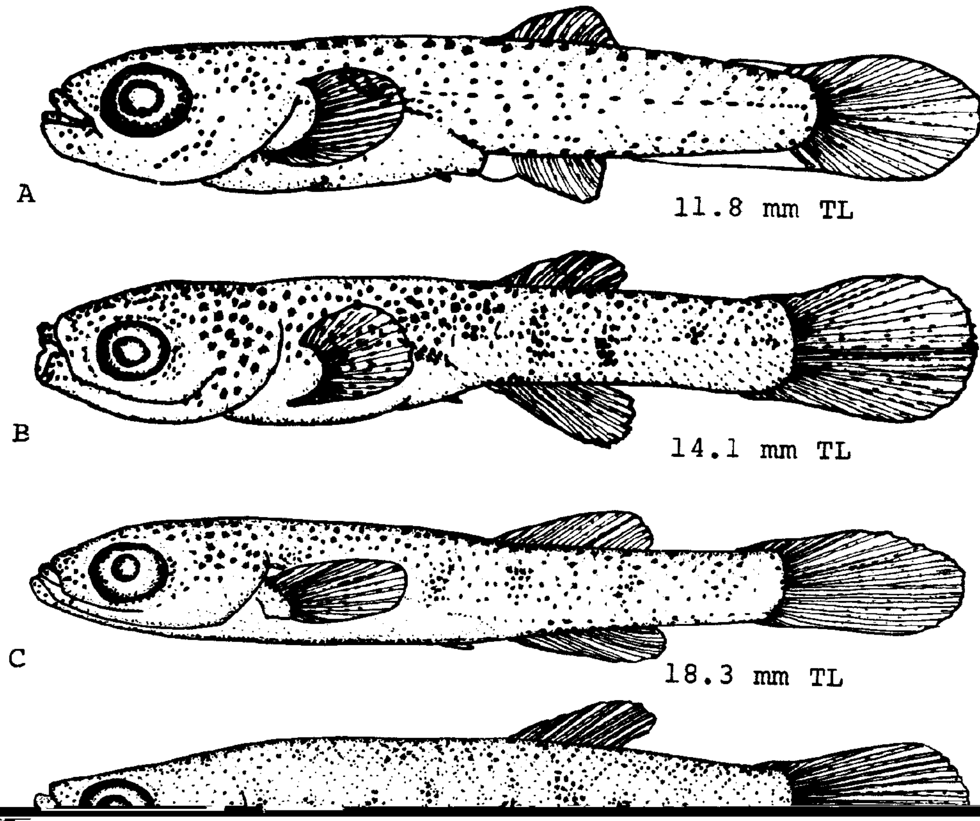
LARVAE

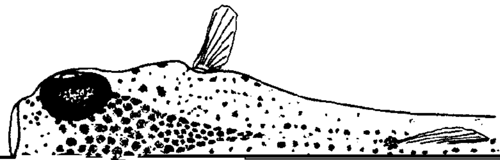
Size range described, 7.0 to 25.4 mm (but also includes some juveniles).[69] Specimens may hatch as larvae (lacking yolk).[71]

Branchiostegals 5 (rarely 6).[69]

Proportions expressed as times in TL at lengths of 7.1–25.4 mm: Head length 3.7–4.6, depth 5.0–7.6, caudal peduncle width 8.9–16.2. Proportions expressed as times in head length at 7.1–25.4 mm: Interorbital width 1.7–3.3, snout length 3.2–5.4, eye diameter 2.8–4.2.

Head blunt, straight; branchiostegals evenly spaced. Dorsal and ventral finfold no longer continuous anteriorly at 11.8 mm, finfold obliterated at 14.0 mm. Dorsal and anal rays evident at 9.0 mm,[67] ray counts apparently complete at 11.0 mm. Pectoral with [87] or without [69] rays at beginning of stage, although specimens of 7.0 mm have pectorals rayed.[132] Pelvic buds evident at 11.0 mm,[67] rays not fully formed at 22.6 mm. Scales first evident above pectoral fin at 12.4–12.7 mm,[69] well-developed at ca. 20.0 mm.[132]


A
11.8 mm TL
B
14.1 mm TL
C
18.3 mm TL



ca. 25.0–26.0 mm, 9–17 (average 12) dark bands, these more narrow than the interspaces in females, wider and more numerous in males. Young males with prominent ocellus on last rays of dorsal. The ocellus is black, margined above and anteriorly by white and may be

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Fundulus luciae (Baird), Spotfin killifish

ADULTS

[redacted]

bars and ocellus intensified and belly, pelvics, anal, lower caudal peduncle and caudal yellowish orange.[35] Females

[redacted]

indentations or submerged wads of decaying vegetation, frequently move in small groups except during cold, overcast weather.[35] Other authors have described *luciae* as a schooling, shallow water species [6,18,23] found in open ocean and estuarine habitats [1,17,34] over sand or mud bottoms; [5,12,19] where sometimes associated with aquatic vegetation.[30] Reported from ditches; [16,26] fresh and tidal pools; [2,11,19,21] shallow, muddy ponds; [14,18] salt ponds; [21] marshes; [14,31] and mouths of creeks; [19] it has been observed to burrow in mud.[30] Depth range less than 10 mm to seldom deeper than 0.5 m except during high spring and storm tides.[35] Salinity range 0.20 ppt [35]–41.0 ppt under natural conditions,[11] although able to survive at 100 ppt under experimental conditions; [36] temperature range 4.0–36.0 C; dissolved oxygen range (natural environment) less than 1.0 to 6.8 mg/liter.[35]

Larvae—no information.

Juveniles—specimens 12.0–22.3 mm long in salinities of 14.85–41.0 ppt in tidal creeks and pools.[11,34]

SPAWNING

Location: Specifically unknown, although mature gonads have been found in specimens from mouths of creeks, over soft mud bottoms;[13] under aquarium conditions:

and May in Chesapeake Bay; late May on Long Island.[13] At Fox Creek Marsh, Virginia, spawning was sporadic and perhaps synchronous when it occurred, but did not correspond with lunar or tidal phases.[35]

Time: Under laboratory conditions specifically observed between 1000 and 1400 hours (JDH).

Temperature: 20 C [35]–30.6 C (JDH) under experimental conditions; in field during natural spawning season temperatures varied from 19–36 C.[35]

Fecundity: Byrne reported a maximum of 16 mature or incipient mature eggs (1.6 mm in diameter),[35] and a range of 4–23 eggs over 0.32 mm in diameter.[14] Richards and Bailey noted 9 late stage ova and 40 "smaller ones" in a single female.[19]

EGGS

Location: Demersal. Location in nature unknown, but in laboratory experiments deposited individually or in clusters of 2–4 on spawning mops, mostly at the base of the mop where strands are most dense.[35,37]

Ovarian and ovulated eggs: Size range 0.32 [35] to ca. 2.0 mm.[23] Twenty "late stage ova" described as clear and with multiple oil droplets (average diameter

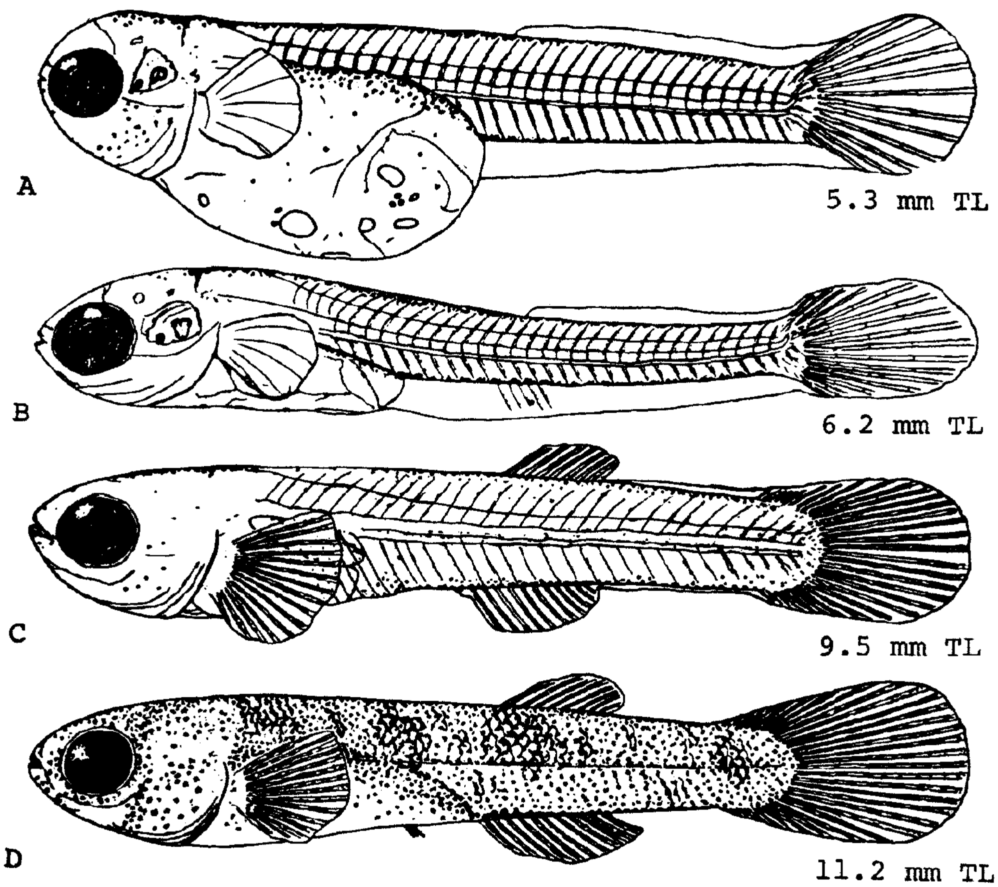


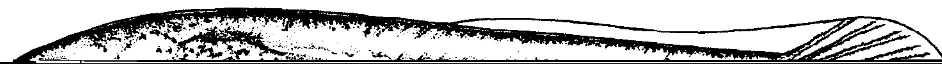
Fig. 107. *Fundulus luciae,* Spotfin killifish. A. Yolk-sac larva, 5.3 mm TL. B. Yolk-sac larva, 6.2 mm TL. C. Larva, 9.5 mm TL. D. Larva, 11.2 mm TL. (*A-D, Byrne, D. M., 1976: fig. 4.*)

sac; mouth terminal, nonprotractile; teeth absent; otoliths evident, the largest about 3 times as large as the smallest. Dorsal finfold forward to between 17th and 18th neural spine (counting from caudal fin). Caudal and pectoral rays evident at time of hatching. In early hatchlings (5.3–6.0 mm) ventral finfold rayless; in more advanced hatchlings (6.0–6.3 mm) anal rays partially formed. Urostyle apparently oblique at 5.3 mm.[35]

lus confluentus, except that lateral yellow spots of *confluentus* are replaced with a solid yellow pigment bar in *luciae.*[38]

LARVAE

Size range 6.0 or 7.0 to 13.0 mm.[35]



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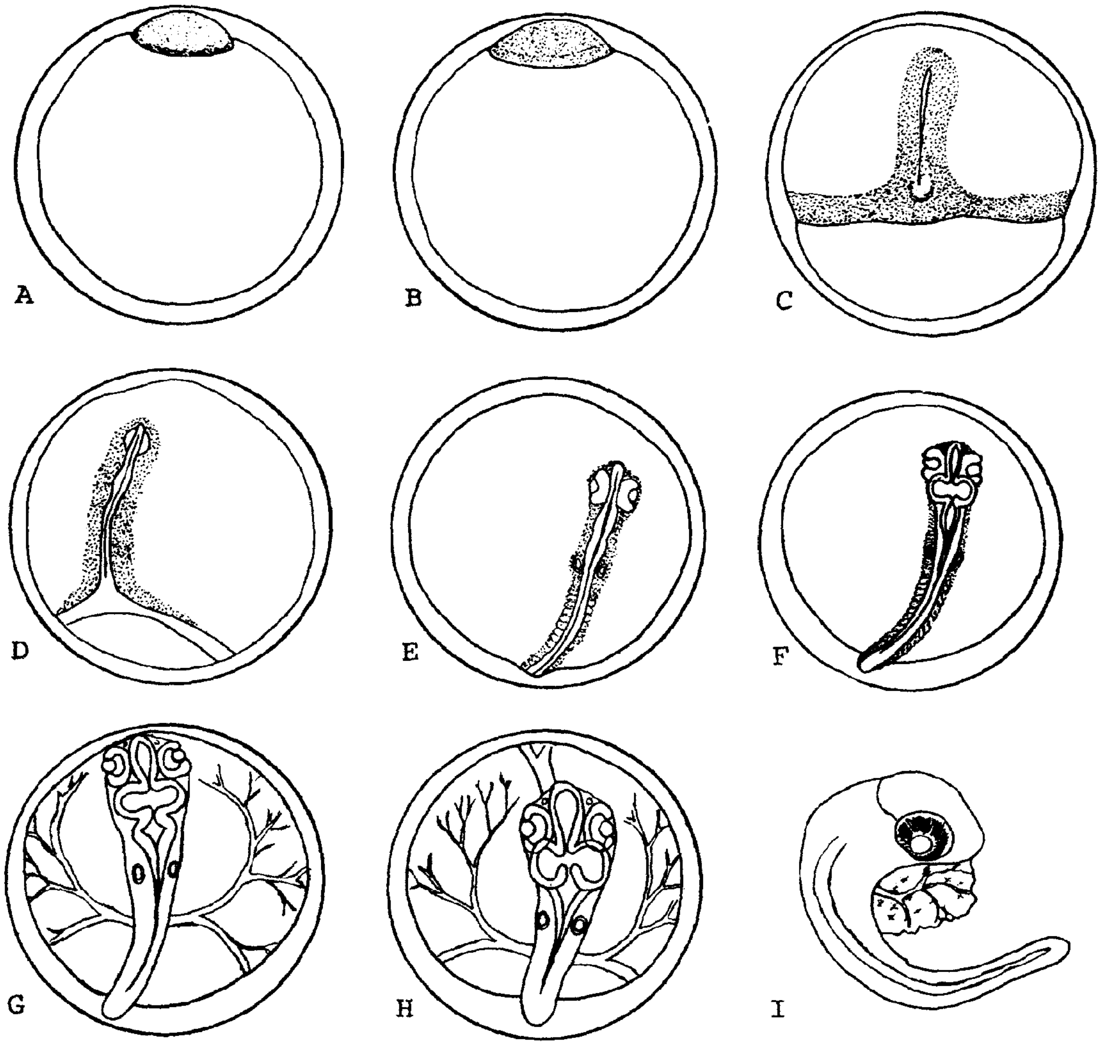


Fig. 111. *Fundulus majalis*, Striped killifish. Development of eggs. A. 18 hours, blastoderm formed. B. 24 hours, blastoderm expanding. C. 48 hours, primitive streak. D. 54 hours, anlagen of embryo. E. 72 hours, eyes, auditory vesicles, somites formed or forming. F. 80 hours, brain divisions evident. G. 96 hours, vitelline vessels evident, no pigment. H. 114 hours. I. 168 hours, pigment in eye and on yolk. *(A-I, Newman, H. H., 1908: pls. 2–4.)*

Habitat and movements: Adults—a schooling species [2,32,47] found in shallow water along sandy or pebbly beaches,[11,50] near mouths of rivers,[1] in salt marshes and fresh waters connecting with them,[40] tide pools,[16,41] sheltered bays,[32,50] bayous,[22,45] creeks,[12,45] guts, and ditches,[41] and around wharves [5] and rubbish piles.[47] Solitary individuals sometimes in muddy water and beds of eelgrass or other aquatic vegetation.[32,47] Move in and out with tide and never found far from shore; [16,38,39,57] capable of moving overland when stranded by receding tide,[12,16] and sometimes in water shallower than their bodies.[58] Overwinter in mud near mouths of creeks.[32,46] Apparently enter freshwater [20,33,40] and able to withstand freshwater in aquaria.[44] Inshore from April or May until fall in Rhode Island.[11] Maximum salinity 37.8 ppt.[57]

Larvae and juveniles—specimens 9.4–51.0 mm long in salinities of 20.4–30.4 ppt; [30] "young" in shallow water among eelgrass and other aquatic vegetation.[21]

SPAWNING

Location: Spawning schools in still shallow water close

[redacted]

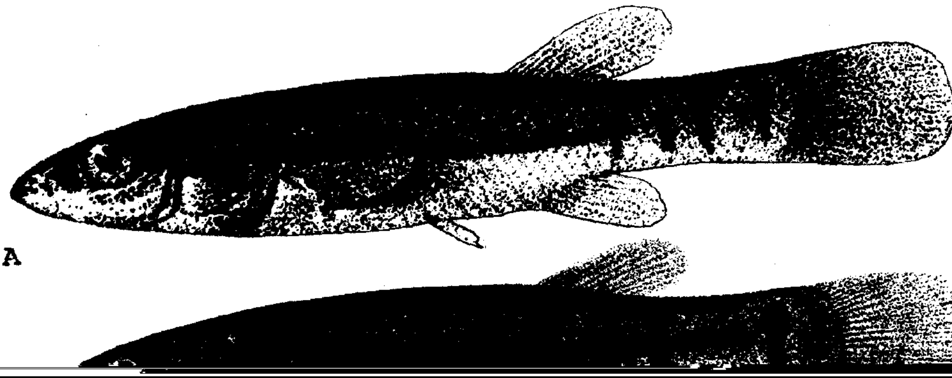
432–480 hours (18–20 days)—hatching.[23]

Development at unspecified temperature (first Newman series): [13]

72 hours—average of ca. 9 somites, no pigment.
80 hours—somites too numerous to count.
96 hours—heart rate slow, beat feeble.
114 hours—vitelline circulation complete.
168 hours—few melanophores on yolk.
288 hours—body with large grayish melanophores, yolk lightly pigmented with black.
528–552 (22–23 days)—hatching.[13]

Incubation period:

At 18.3 C	Ca. 58 days.[32]
At 16–20 C	First hatch 34 days, 50% hatch 41 days.
At 22–26 C	First hatch 14 days, 50% hatch 17 days.
At 28–32 C	First hatch 10 days, 50% hatch 12 days.
At 22–26 C transferred to 16–20 C	At 3–6 somite stage, first hatch 40 days, 50% hatch 40 days.
	At 9–12 somite stage, first hatch 35 days, 50% hatch 39 days.
	At 15–23 somite stage, first hatch 31 days, 50% hatch 31 days.
	At 24–28 somite stage, first hatch 27



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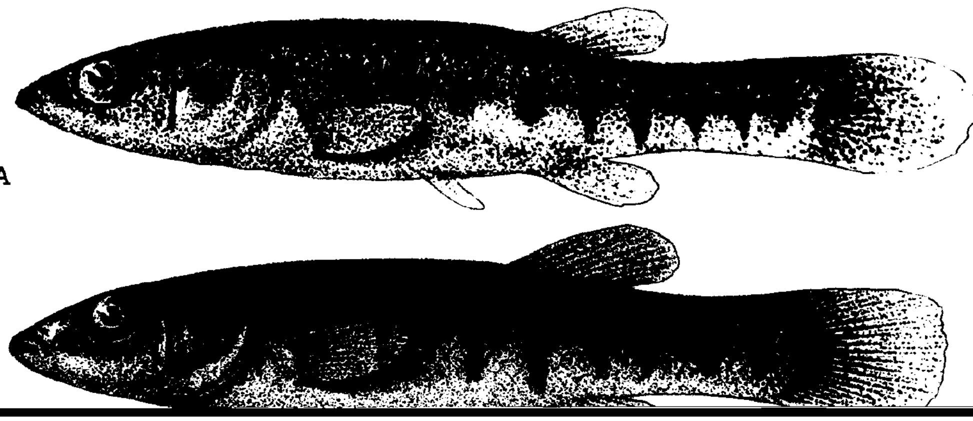

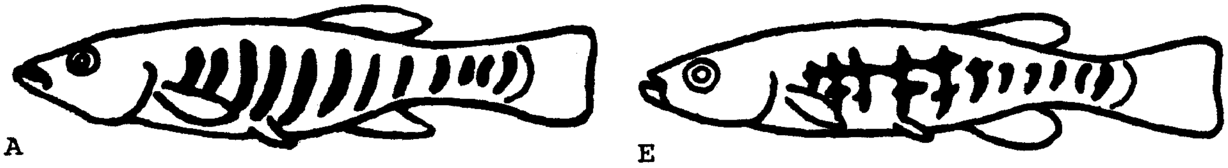
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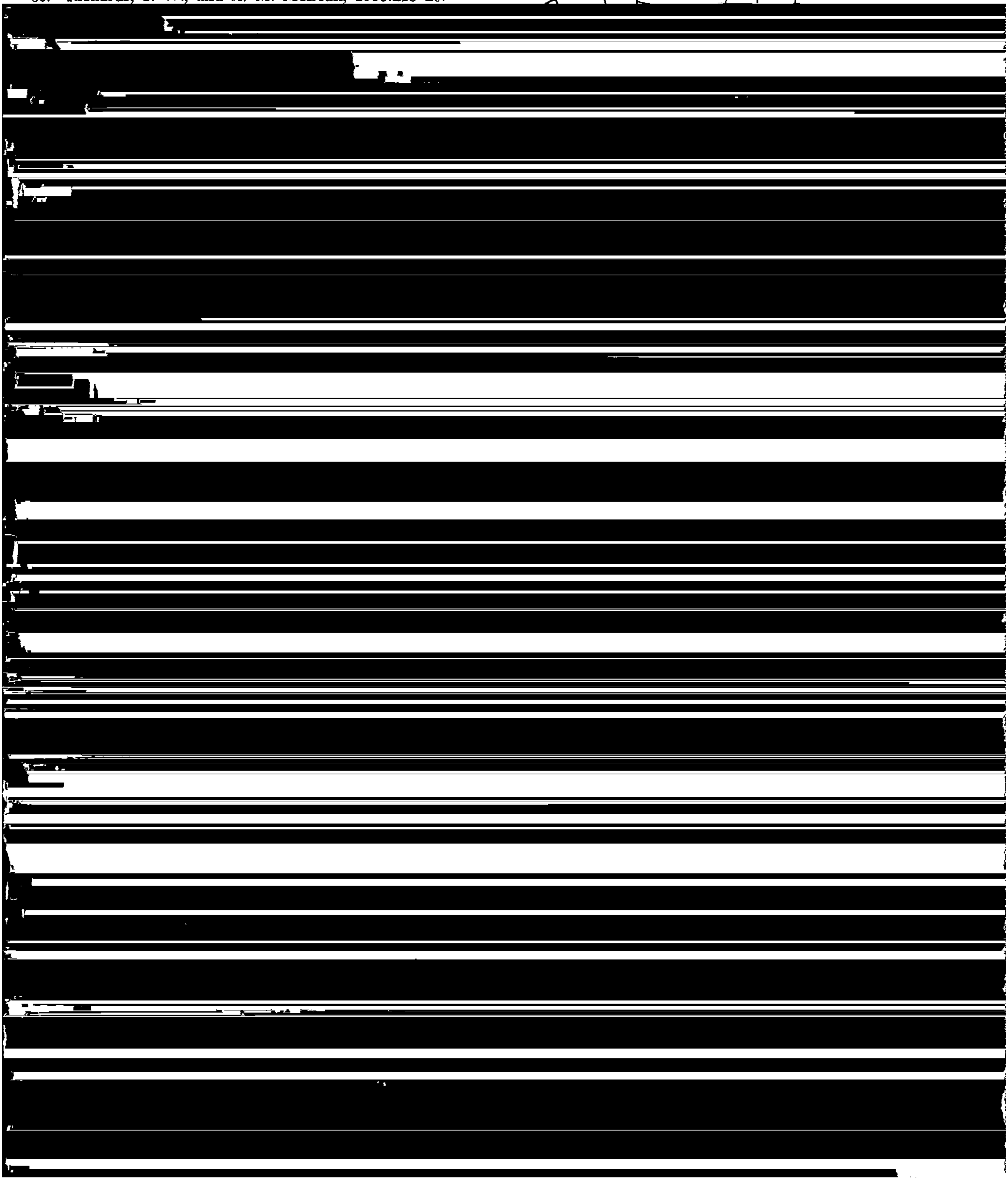


Lucania parva (Baird), Rainwater killifish

ADULTS

D. 9–14, mean 10.96, unbranched 1–4, branched 7–11; A. 8–13, mean 9.49, unbranched 1–4, branched 5–10; C. 12–18 principal rays, mean 15.68; P. 10–15, mean 13.31; V. 4–7; lateral line scales 23[5]–31,[41] mean 26.83; scales between origin of dorsal and anal 8–11, mean 9.3, scales around body 18–25, mean 21.92, scales around caudal peduncle 10–16, mean 14.97,[5] scales in oblique series between upper angle of gill opening and dorsal origin 6–7; [43] vertebrae 14 + 14,[40] but total vertebrae vary from 25–30, overall mean 27.73, mode geographically variable, stated as 26, 28, and 29; branchiostegals 5–6; preopercular pores usually 7; supraorbital canal complete to incomplete, typically with 7 pores; lachrymal pores 0–5; mandibular pores 0–5.[5]

Depth as times in SL ca. 2.6–4.5, mean 3.56; [5] head in TL 3.25[33]–3.70. Proportions expressed as percent SL:

with black; [39] anal and pelvics pale orange [35] to orange-red,[18,33] or pinkish,[41] their edges bordered with dusky [18,33] to jet black; [21] anal sometimes faintly washed with gold; [41] pelvics also described as yellow with maroon-orange or dusky edges, anal as green or maroon with black edge; [38] caudal fin orange-yellow [18] or dusky, edged with clear,[39] dusky,[21] or black; [33] pectorals translucent,[18,33] or rarely, black.[41] Breeding males usually with "crosshatched" pattern on sides of body.[41]

Maximum length: 62.0 mm,[35] the females larger than males.[33]

DISTRIBUTION AND ECOLOGY

Range: Cape Cod, Massachusetts, to lower Rio Panuco system, Tamaulipas, Mexico; primarily coastal, but with inland populations in Florida and the Pecos River, New Mexico; apparently introduced in California, Oregon,

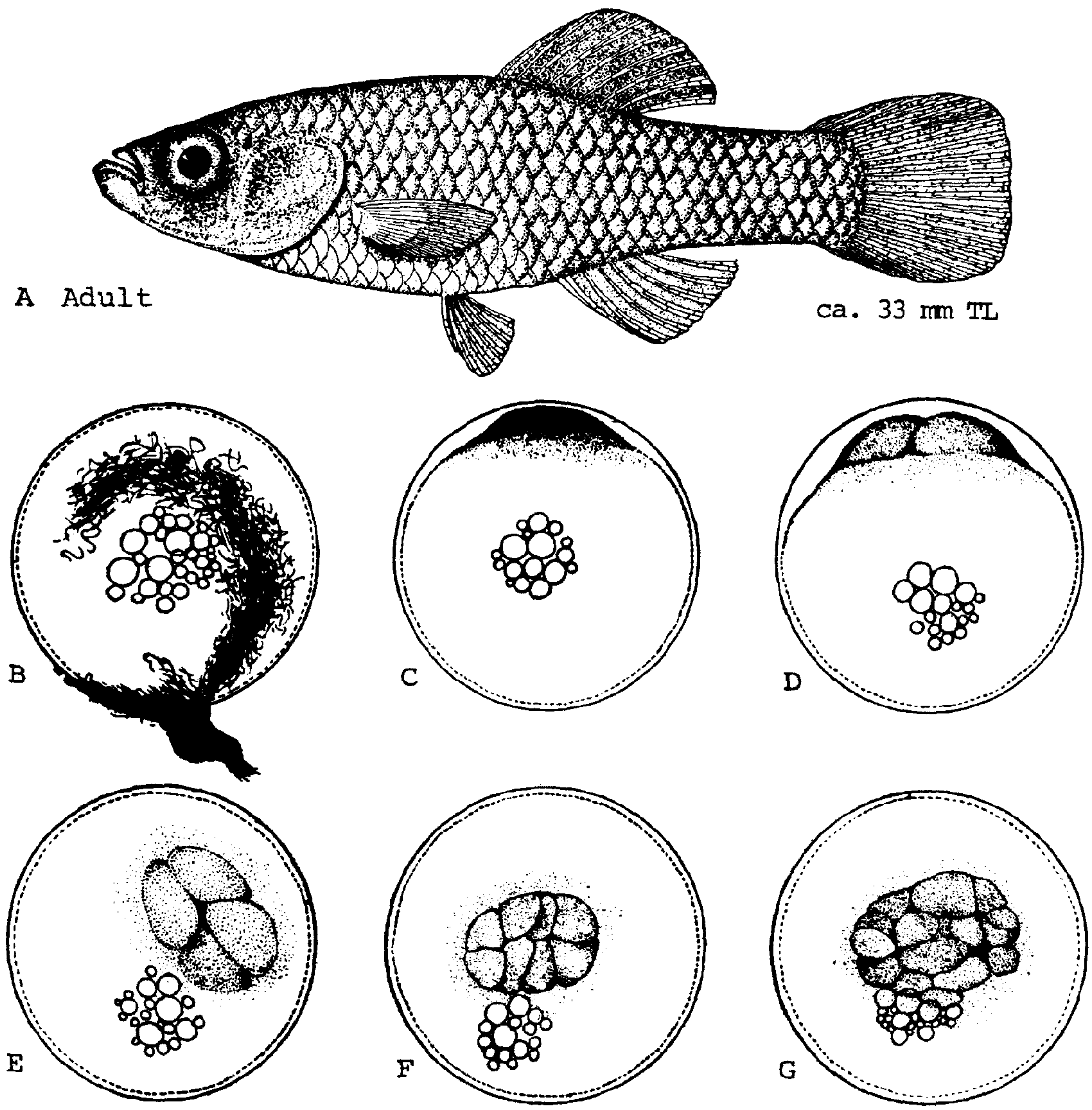


Fig. 121. ***Lucania parva***, Rainwater killifish. A. Adult, ca. 33 mm TL. B. Mature unfertilized egg showing attachment filaments, diameter 1.1–1.3 mm. C. Blastodisc. D. 2-cell stage. E. 4-cell stage. F. 8-cell stage. G. 16-cell stage. (*A, Bean, T. H., 1888: pl. 2. B-G, Kuntz, A., 1916: figs. 16–21.*)

Season: In Chesapeake Bay ripe or nearly ripe fish early April to end of July; [30] in North Carolina, mid-April to late August; [16] in Texas ripe individuals from late January to July, peak activity May and June; [35,41] in Florida February to October; [39] or more or less continuous throughout year.[11] More than one brood may be produced per year by a single female.[16,30]

Temperature: Ca. 17.8 C in aquaria.[10,28]

Fecundity: 7–46 ripe ova (mean 24.5 per fish) plus "many smaller ova"; [39] maximum reported count 104.[30]

EGGS

Location: Demersal, deposited on fibrous substrate near surface or on bottom in shallow water; [42] in aquarium experiments on floating spawning mops, always near top.[44]

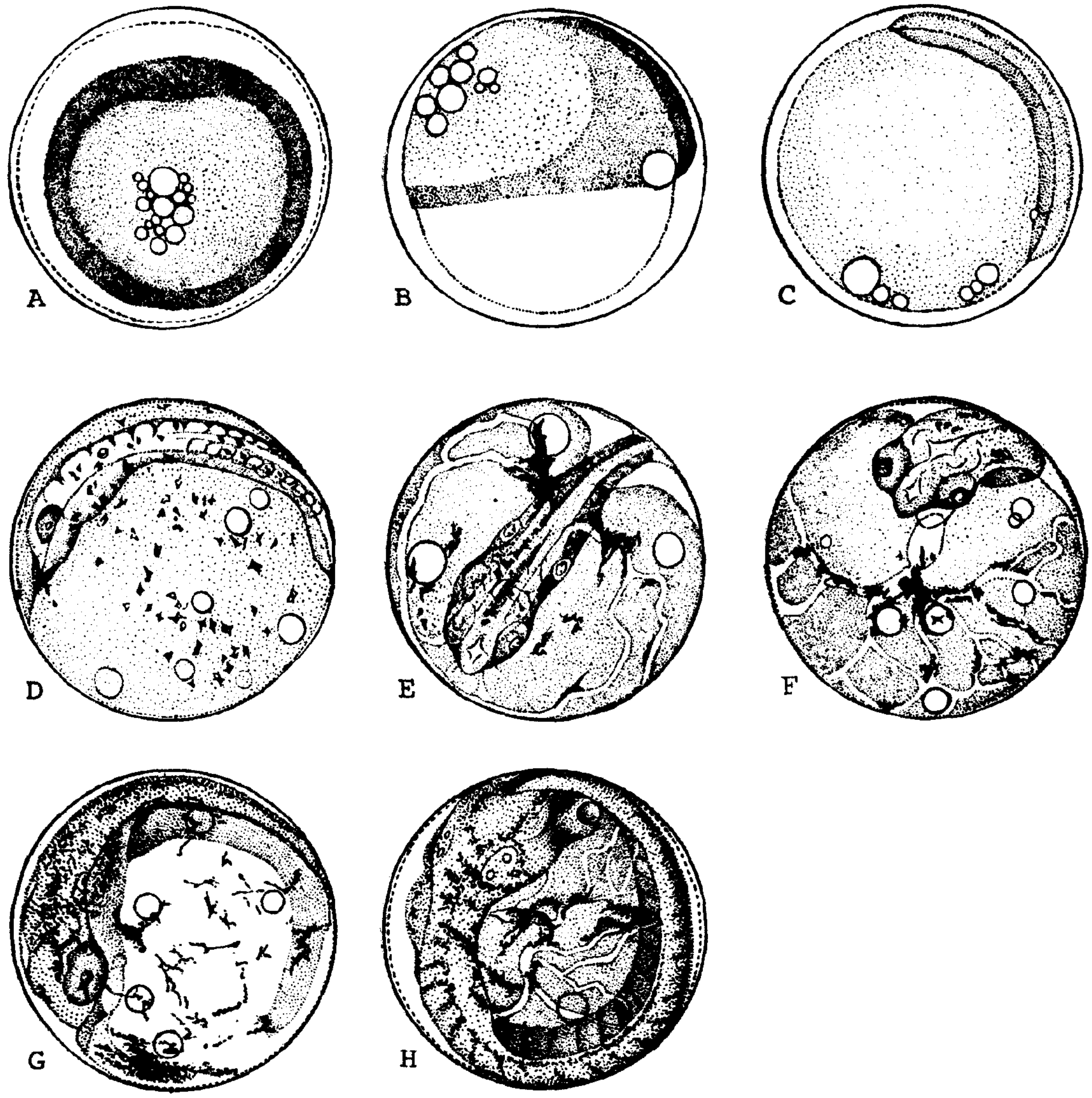


Fig. 122. *Lucania parva*, Rainwater killifish. A. Blastoderm showing germ ring. B. Germ ring and embryonic shield. C. Kupffer's vesicle, 24 hours. D. Early pigmentation, somites evident, 48 hours. E, F. Yolk circulation established, chromatophores along yolk vessels, otoliths formed, 68 hours. G. Advanced embryo, 90 hours. H. Prehatching stage, tail completely around yolk, pigmentation heavy. (*A-H, Kuntz, A., 1916: figs. 22–29.*)

Unfertilized eggs: Spherical; 1.0–1.3 mm in diameter; slightly yellowish, transparent; micropyle small; oil globules unequal, normally 12–20 at animal pole; egg membrane equipped with tangle of coarse adhesive threads which hold eggs loosely in clumps; perivitelline space narrow.[9,16,30,31,39]

Fertilized eggs: Diameter 1.0–1.3 mm,[44] average 1.23; [43] outer membrane relatively thick, horny; [42] attachment filaments typically most abundant in one area of egg surface; [44] perivitelline space very narrow.[42]

EGG DEVELOPMENT

Development at laboratory temperature: [16]

1 hour—blastodisc formed.

1 hour, 15 minutes—first cleavage.

13 hours—germ ring differentiated.

24 hours—blastopore closed, Kupffer's vesicle formed, embryo less than 1/2 yolk circumference.

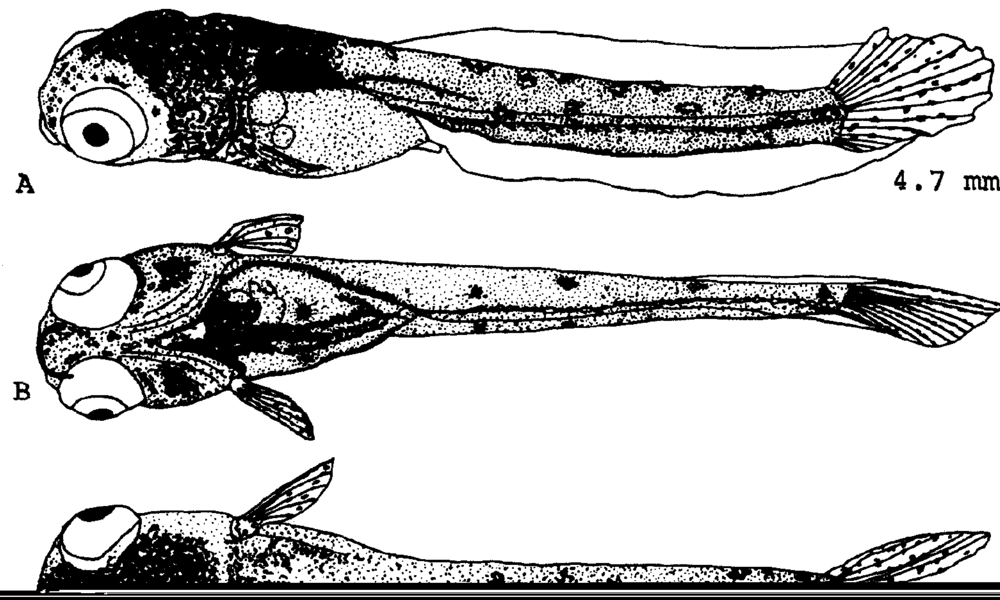
"Soon after closure of blastopore"—melanin granules in cells.

44–48 hours—embryo segmented throughout, auditory vesicles evident, circulation established, melanophores and yellow chromatophores developed on yolk sac and body.

68 hours—otoliths evident, yolk with heavy vascular [redacted]

Total myomeres, 8 + 18.[46]

At time of hatching head large,[42] not deflected over yolk;[16] margin of operculum more than half distance from snout to vent,[42] yolk sac large; origin of dorsal fin- [redacted]



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Gambusia affinis

livebearers
Poeciliidae

FAMILY POECILIIDAE

The family Poeciliidae contains 21 genera and 138 species and was originally limited to tropical and subtropical waters of North, Central, and South America. Certain of its members have now been introduced, either accidentally or as potential mosquito control organisms, into other parts of the world. *Gambusia affinis*, the only regional member of the family, now occurs, for example, on all of the continents and a number of oceanic islands. Some species are remarkably ubiquitous, occurring in a wide variety of habitats including saltwater.

Poeciliid fishes may be characterized as follows: females are either viviparous or, rarely, ovoviviparous; males have a well-developed intromittent organ, the gonopondium, and produce spermatophores; fertilization is usually internal; the mouth is terminal and directed upward; the caudal fin is rounded; and there is a single dorsal fin which lacks spines. Sexual dimorphism is common within the group and may involve fins, mouth parts, ribs, and cranial structure, in addition to pigment.

In all poeciliids except the South American *Tomeurus*, spermatophores are introduced directly into the gonoduct of the female by the male gonopodium. In *Tomeurus*, spermatophores are applied externally to the area around the genital opening. Once introduced into the female gonoduct, the spermatophores immediately disintegrate, releasing individual sperm. Sperm can be stored for long periods of time and fertilize several successive batches of eggs.

Some of the species within this family, such as *Poecilia formosa*, are comprised entirely of females. In these, sperm is derived through matings with males of other species. In other species, two kinds of females occur: Those which produce only female offspring, and those which produce a normal ratio of male and female offspring. Hermaphroditism has been suggested in several species, but apparently has not been well documented.

In all members of the family except *Tomeurus* the eggs lack a chorion. Development occurs primarily in the ovaries, and ovulation (follicular rupture) does not take place until long after fertilization. Developing embryos are nourished both by yolk and, at least in part, directly by the female, and the extent of direct nourishment appears to vary from species to species. In *Tomeurus* the eggs have a chorion and well-developed long attachment filaments. Development begins internally, but the eggs are subsequently released and attached to plants and sand grains.

Young may be born with or without yolk, and, except in *Tomeurus*, development of the fins and scales is remarkably precocious.

Gambusia affinis (Baird and Girard), Mosquitofish

ADULTS

sal, with lower jaw projecting beyond upper.[22] Teeth below; pupil blackish. Dorsal fin pale translucent[73] or slightly greenish[95] and with 2–3 transverse rows of fine black dots;[31,40] pectoral and pelvic fins dusky.[31,73] Fe- [redacted]

springs;[22,62,118] bogs;[82] cypress, tupelo-oak, and mangrove swamps;[27,94,111] bayous; woodpools; flooded pine flatwoods;[14,59,118] lagoons;[82] coves; and backwaters[7,9] [redacted] with longer periods between broods in winter,[17,54,63,131] and apparently with peak activity from March to October in some areas; [118] in Louisiana, March 15 to October 1 or slightly later; [59] in Mississippi, gravid females in "practically all months"; [130] in Texas, peak activity in April; [72,81] in Oklahoma, March to late September and again in November; [24] in Montana, March through October; [132] at Winnipeg, Canada, gravid females as late as October; [51] in Russia, late May and early June; [82] in Portugal, reproductive activity as early as January, breeding April to September; [57,76,108] in Italy, all months except October; [107] in Egypt, April to September; [49] in India, throughout year, but with peak activity in October and November; [23,66,84] in Japan, March to October, with peak activity from May to September.[122] Under laboratory conditions young have been produced from early December to late June and in November and January; [13,71] in laboratory specimens from Maryland, January to June.[129] Length of reproductive period varies with individual fish: in Illinois 8–10 month old females are reproductively active for 10–15 weeks; those which begin reproducing during summer of birth are active for 4–10 weeks.[60]

Brood frequency: 2 [10,45] to 8 broods [102] per reproductive season. Interval between broods varies from 19 [107] to 85 days, although, following the birth of young, the next batch of eggs may be ready for fertilization within 10 days.[39] Average times between broods have been recorded as 20.5 [107] and 35 days.[127]

Reproductive temperature: Ca. 15.5 C [72]–30 C.[122] A critical temperature of ca. 15.5 C has been established [72] although in other experiments a temperature of 20 C was needed to induce breeding [36] and breeding ceased if the temperature dropped below 18 C.[64]

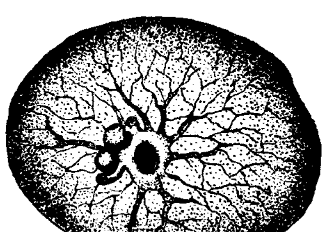


Fig. 126. *Gambusia affinis*, Mosquitofish. A. An ovarian follicle containing an embryo and showing the follicular pore. Two immature eggs are attached near the pore. (*A, Ryder, J. A., 1885a: fig. 11.*)

Fecundity: Apparently highly variable. Number of young from a single brood varies from 1 to 315,[22,132] although only 345–428 young may be produced by one female in a single season which may include up to 5 broods.[54,82] Published average brood sizes: 11.3,[118] 24,[10] 33 (in 50–60 mm fish),[114] ca. 40,[54] 41.5, 43,[107] ca. 50,[63,124] and 100.[10] Six investigators give total fecundities of less than 50; [3,13,19,36,40,85] nine give totals between 50 and 100; [50,59,64,84,86,87,113,114,118] one gives up to 200; [63] two give figures in excess of 200; [59,105] and two give figures higher than 300.[22,44] Ovarian egg counts (as opposed to counts of ripe eggs or embryos) vary from 20 [110]–240.[23] Fecundity apparently increases with increasing size of female.[50,59,60] Broods become smaller as season progresses,[45] although the 4th brood for an individual female is usually the largest; [107] one author found that broods varied from 84–135 in June with a mean of 100, to 18–30 in August with a mean of 24.[10]

EGGS

Location: Developed entirely within the ovaries; each ovum enclosed in a Graefian follicle, ovisac, or ovarian capsule, surrounded by fluid, and having independent blood supply.[3,12,110]

Immature ovarian eggs—diameter 0.3–0.7 mm at time that earlier embryos are ready to be born; still immature at 1.7 mm diameter; [39,110] egg membrane absent; [3,12,110] micropyle apparently replaced by "follicular pore." [110]

Ripe ovarian eggs (although description probably contains some information based on fertilized eggs)—diameter 1.6 [59]–2.1 [3] or, possibly, ca. 3.0 mm; [42] golden yellow [114] and transparent [42] or with orange, opaque yolk; a thin vitelline membrane; [114] each egg attached to central nucleus of ovary by thread or membrane; [42] entire surface of egg with many small refringent oil globules of various sizes.[3,110,114]

Fertilized eggs—at segmentation diameter 1.6–1.9 mm, at late embryo stages diameter 1.5–2.4 mm.[103]

EGG DEVELOPMENT

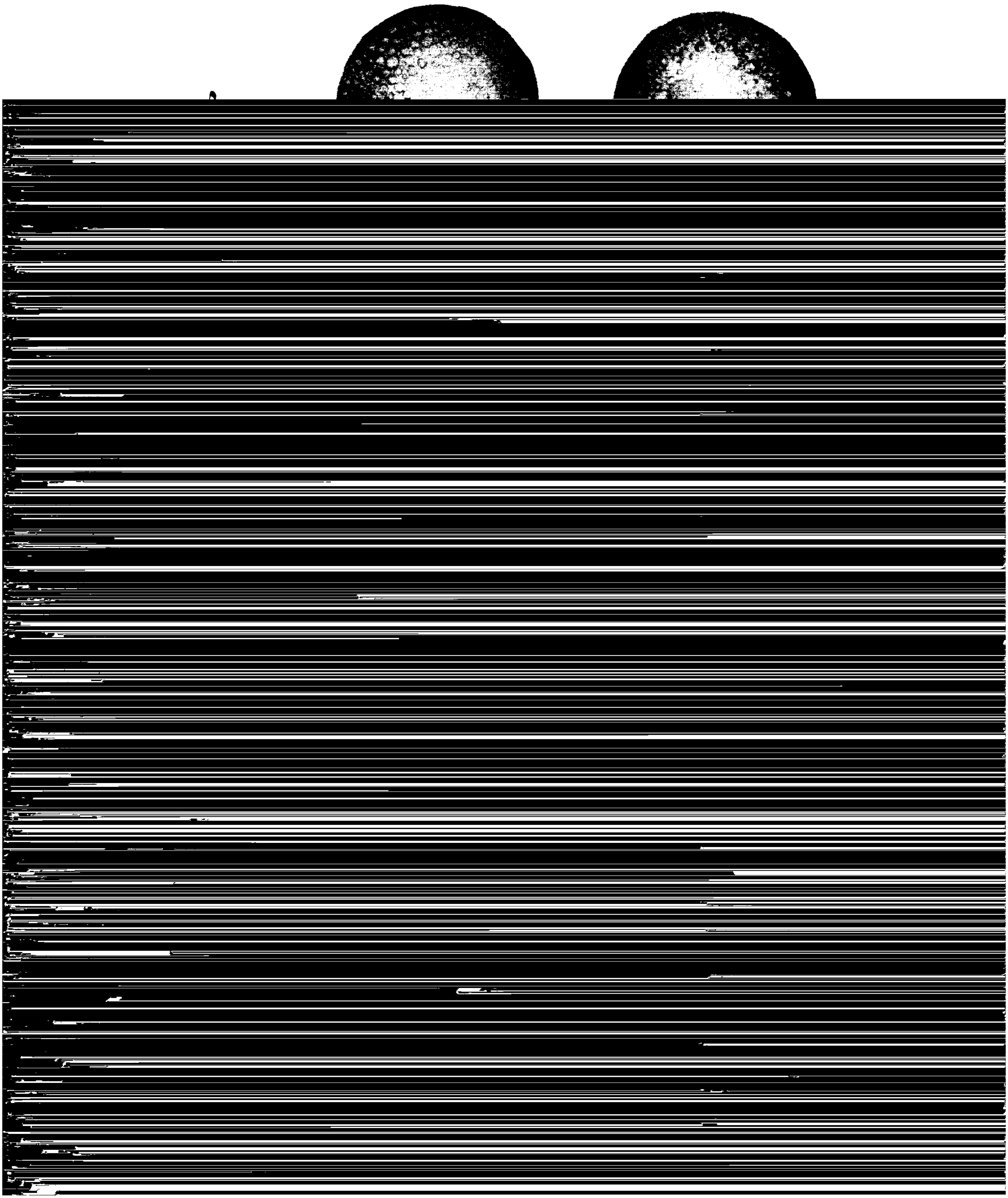
Development at unspecified temperature (the Medlan series): [72]

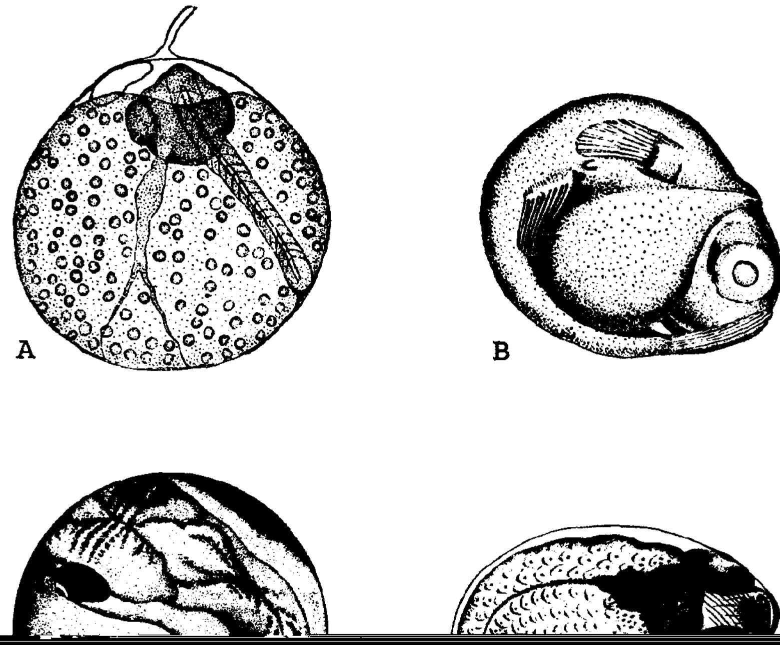
3.0 mm embryo—buccal cavity wide; esophagus curved to right side; intestine with single coil; swim bladder, liver, spleen, and pancreas formed; heart pulsating; sinus venosus, auricle, and ventricle established; mesonephric kidneys formed; Wolffian ducts open directly to outside posterior to anal opening; gonads visible as paired structures on each side.

4.0 mm embryo—essentially like 3.0 mm embryo, except that sexes can now be differentiated.

5.0 mm embryo—esophagus constricted, liver markedly increased in size.

6.0 mm embryo—yolk mass noticeably decreased; lateral body wall extends over yolk; snout protrudes through respiratory portal system; chromatophores scattered on upper surface of embryo and concentrated on





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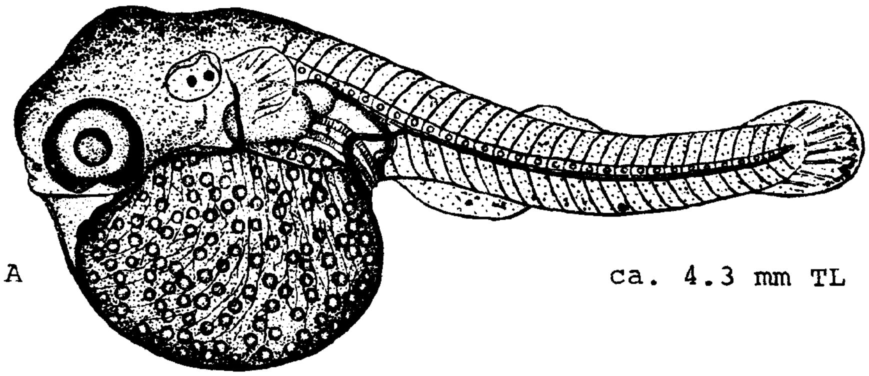
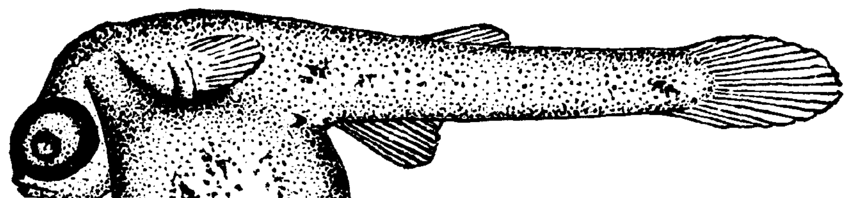


A ca. 4.3 mm TL



Early stages—multicellular blastoderm developed as small almost circular cap slightly elevated above surface of yolk; as blastoderm increases cleavage cavity becomes visible; germ ring never well defined, developed as thickening at edge of blastoderm; cleavage cavity becomes somewhat triangular; blastoderm elongates somewhat prior to formation of embryonic shield.

3–4 somite stage—anlage of neural axis apparent throughout, optic vesicles well formed; tail bud evident.

12–14 somite stage—auditory vesicles present, heart differentiated as single curved tube.

Pigmentation (all stages)—scattered chromatophores first appear on dorsal surface, and are more closely aggregated on posterior region of head and along mid-

2.0 mm stage—notochord a rounded, continuous rod mainly composed of vacuolated cells.

4.0 mm stage—vertebral centra formed, distinct up to 24th vertebra; indications of vertebral and intervertebral portions of notochord evident.

6.0–7.0 mm stage—vertebral column definitely differentiated into vertebral and intervertebral parts.[47]

Miscellaneous comments on development:

Eyes may be evident in embryos as small as 1.0 mm.[118]

Primary germ cells first develop in the mesoendodermal layer in the early gastrula; [126] definitive sex cells have been observed beneath the gas bladder in embryos

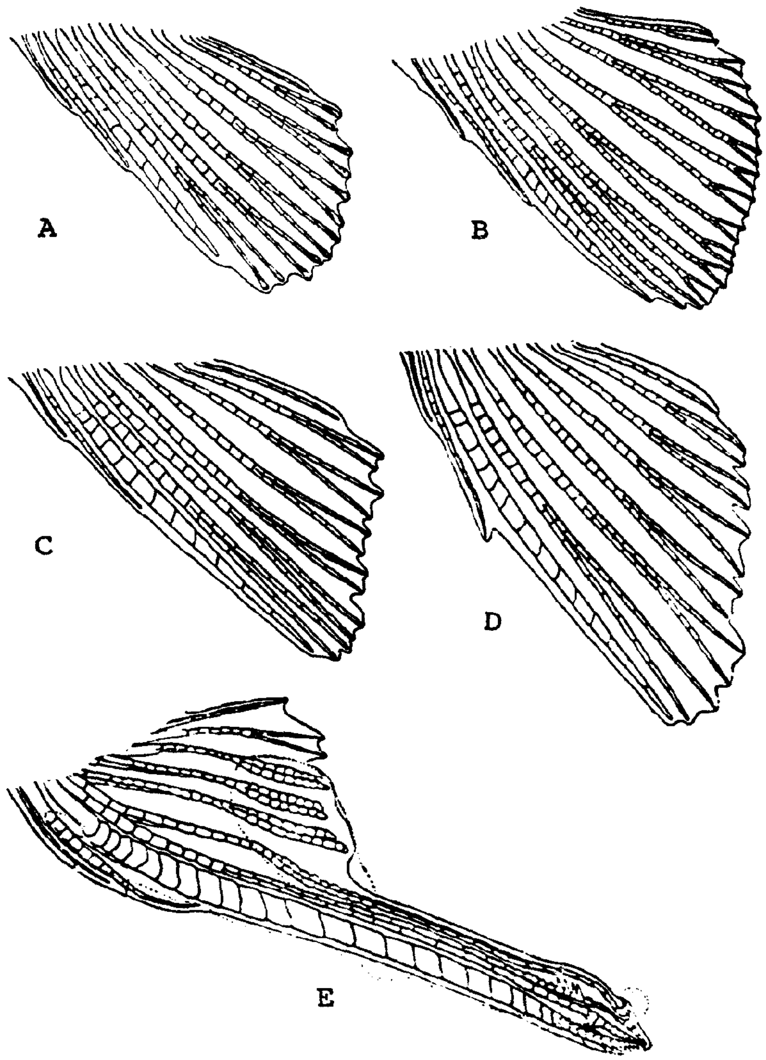


Fig. 131. *Gambusia affinis*, Mosquitofish. Development of the anal fin and gonopodium. A. Female, 15 mm TL. B. Female, 30 mm TL. C. Male, 12-segment stage. D. Male, 15-segment stage. E. Male, mature gonopodium. (*A-E, Turner, C. L., 1941b: figs. 7–11.*)

although one author states that 10–300 young are expelled "at one time." [44]

YOLK-SAC LARVAE

Length apparently just after birth, 5.1–6.2, $\bar{x}$ 5.5 mm.[103] Length at birth 7.0 [43,72]–ca. 12.7 mm.[42] At least some specimens ca. 7.4 mm or longer are born without yolk,[114] while others up to at least 8.0 mm retain yolk.[23]

Trunk vertebra 11, caudal vertebrae 21 at birth (there is a subsequent shift of trunk features into anterior part of original tail region).[16]

Body initially curved, but straightened after birth; [42] yolk mass visible at birth, but completely enclosed by lateral body wall; [72,99] teeth functional at birth; [96] during "early development" testes separated except at posterior ends; [119] posterior part of gas bladder thin-walled and expanded, pneumatic duct a solid ligament at birth.[72]

Anal fin of male and female (stage uncertain) with 10 rays and identical.[23]

Pigmentation: Sometimes transparent and with black eyes,[23] and sometimes well pigmented.[42]

LARVAE

Size range described: 7.4 [114]–15.0 mm.[77]

In specimens born without yolk the adult number of lateral line and transverse scales is established. At ca. 7.4 mm dorsal, anal, caudal, and pectoral fins are free and fully rayed.[114] At ca. 8.0 mm anal fin of female shows beginning of anchylosis of certain basal segments of all rays (this feature can be used to distinguish sexes in specimens of this size).[78] At 8.2 mm (11 days after birth) anal fin presents the following segmentation formula: 2,4,5,8,8,8,8,6,4,2.[79] At 13.0–15.0 mm pectoral fins of both sexes with 13 bony rays, each segmented except for basal third.[77]

Pigmentation: Often uniformly yellowish, with dusky fins and cross series of dots in caudal fin.[31] At ca. 7.4 mm a prominent blotch of pigment, elongated posteriorly, on back of head; chromatophores on head and upper sides, and in discrete row in mid-lateral region; also on membrane of some fins. At 9.0–10.0 mm light olive, darker above than below; a fine line along side; 2–3 transverse rows of dark spots on dorsal; dark margin on anal fin; 3–4 rows of dark spots (characteristic of female) differentiating on caudal fin.[114]

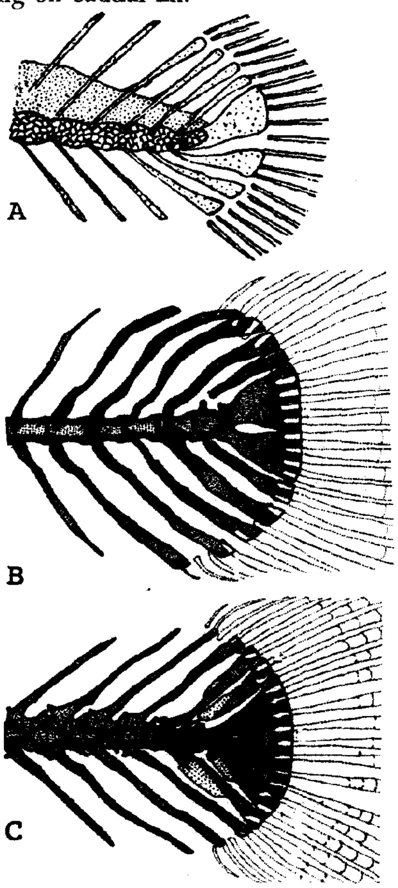


Fig. 132. *Gambusia affinis*, Mosquitofish. Development of caudal skeleton. A. Tail of advanced embryo showing hyaline notochord. B. Embryo, 5.0 mm TL. C. Adult female, 23 mm TL. (*A, Ryder, J. A., 1885a: fig. 18. B, C, Hollister, G., 1940: figs. 12–13.*)

JUVENILES

Minimum size described 13.0 mm.[113]

Anal fin tends to be more pointed in immature males than immature females.[74] Anal fin of male begins to differentiate in contour from that of female at sizes varying from 13.0–17.0 mm;[113] up to 10-segment stage (counting segments in 3rd ray) contour of fin is same in both sexes; at 9-segment stage rays 4 to 9 divide at ends and new terminal segments are added to the branches, anchylosis of joints of the rays begins basally and proceeds apically (in the male this process ends after eradication of a single intersegmental space, in the female it continues throughout life); at 9- to 10-segment stage 3–5 intersegmental spaces disappear or persist only faintly in female so that basal solid segment is longer than that in male.[79]

Sexual differentiation evident at 14 mm, complete by 21st day.[124] At 2–3 months testes fused more or less completely along median line.[119]

Pigmentation: No information.

AGE AND SIZE AT MATURITY

Age at maturity, 28 days[31] to second summer of life;[60] size at maturity, for males 18.0[29]–28 mm[77] (possibly as small as 13.0 mm[43]), females 22[101,132]–34.0 mm.[13]

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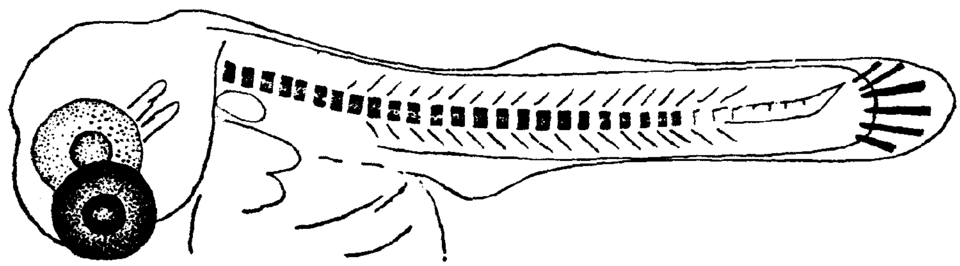

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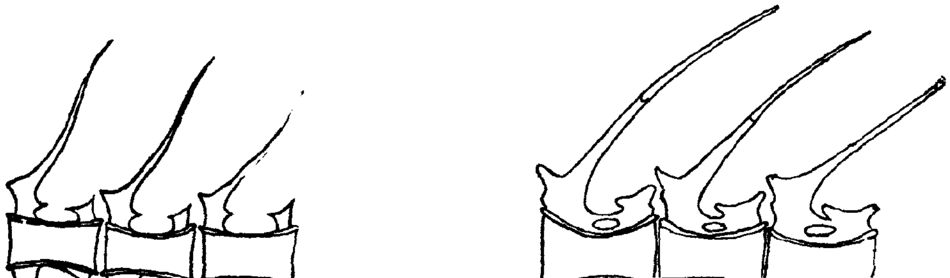

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[redacted]

Enchelyopus cimbrius
Gadus morhua
Melanogrammus aeglefinus
Microgadus tomcod
Phycis chesteri
Pollachius virens
Urophycis chuss
Urophycis earlii
Urophycis regius
Urophycis tenuis

codfishes
Gadidae

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FAMILY GADIDAE

Gadid fishes occur in arctic, boreal, and subtropical waters of the northern hemisphere and, sometimes, in cool waters of the southern hemisphere. The family, as herein defined, contains 21 genera and approximately 55 species.

Although primarily found in oceanic waters where they have been recorded at depths greater than 1000 meters, one species, *Lota lota*, is restricted almost entirely to freshwater. Others, such as *Microgadus tomcod* and *Gadus morhua*, sometimes enter fresh or estuarine waters.

Gadid fishes are distinguished by the following characteristics: the head of the vomer is toothed, the gas bladder is not connected to the auditory capsules, the teeth in the jaws are small and in wide bands, the scales are cycloid, and the first vertebra is attached to the skull. In the subfamily Gadinae there are three dorsal fins and two anal fins. The caudal fin is truncate or slightly forked and barbels are usually present on the chin. In the Lotinae there are one or two dorsal fins and one anal fin. The caudal fin is round and chin barbels are always present.

Little is known of the spawning of these fishes. Males of the Atlantic codfish defend territories on the bottom, but go through a distinctive courtship pattern which terminates with spawning at or just below the surface. In the haddock, in which spawning occurs while the male and female are swimming upward, sound production may be an important aspect of courtship behavior.

Eggs of gadid fishes are typically small, and may be either adhesive or nonadhesive, even within the same species (as in *Microgadus tomcod*, for example). A number of species, such as members of the genera *Enchelyopus, Phycis, Urophycis, Brosme, Molva,* and *Raniceps*, produce eggs having one to many oil globules. In the eggs of *Microgadus tomcod* there may be a number of very minute oil globules. Oil globules are entirely lacking in other gadid fishes such as *Gadus morhua, Melanogrammus aeglifinus,* and *Pollachius virens*. A few members of the family (*Microgadus* and *Lota*) produce demersal eggs, but most species have either pelagic or buoyant eggs. Pertinent data on eggs of the gadoid fishes of the Mid-Atlantic Bight are presented in table 5.

Larvae of gadid fishes may be characterized as follows: the anus is one-third to two-fifths the distance to the tip of the tail; as development proceeds, the gut becomes distinctly coiled; the anal opening is at the side, not the edge of the finfold; and pigment is developed at the time of hatching or very shortly thereafter. Among the regional gadid fishes the pelvic fins develop precociously in *Enchelyopus cimbrius, Urophycis chuss,* and *Urophycis regius* and probably also in *Phycis chesteri, Urophycis earlli,* and *Urophycis tenuis*. Gadid larvae are generally pelagic, and those of a number of species characteristically become associated with jellyfishes. In some gadid species there is a distinct prejuvenile stage characterized by remarkable changes in pigmentation associated with a descent from surface to bottom waters. The prejuveniles of some genera (*Gaidropsarus*, for example) are so different from the adults that they were originally thought to belong in different genera.

Key to yolk-sac larvae of gadoid fishes of the Mid-Atlantic Bight:

1A. Yolk-sac larvae undescribed . . . . *Phycis chesteri*
. . . . *Urophycis earlli*
. . . . *Urophycis tenuis*

1B. Yolk-sac larvae described 2

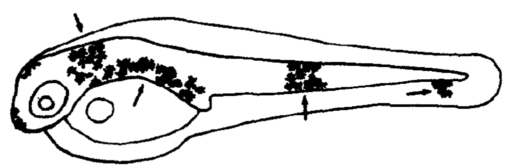
2A. Yolk without oil globules, or, rarely, with several very minute oil globules 7

2B. Yolk always with a single large oil globule 3

3A. Less than 18 preanal myomeres 4

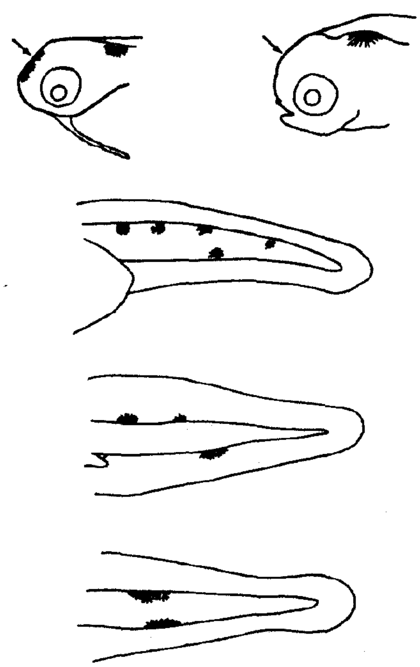
3B. More than 24 preanal myomeres 6

4A. A distinct pigment blotch ventrally in finfold at tip of tail; a single broad band of pigment at midpoint of tail, and, usually, a broad band of pigment on body just behind head; length 1.63–3.0 mm . . . . *Enchelyopus cimbrius*

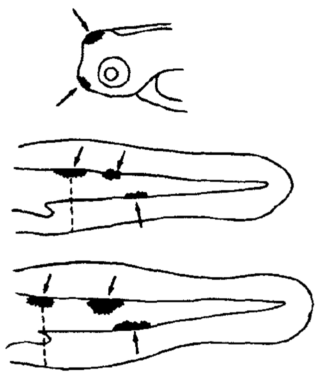


4B. No pigment blotch in finfold at tip of tail 5

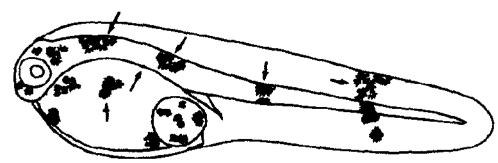
5A. Pigment blotches on head initially crowded together on anterodorsal profile, entirely absent by end of stage; initially with 4 or 5 melanophores on body beyond anus, then with 2 dorsally and 1 ventrally, then, usually, with 1 above and 1 below; length 1.76–2.2 mm . . . . *Urophycis chuss*



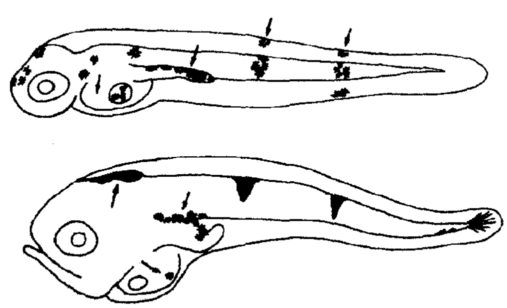
5B. Pigment blotches on head widely separated, one on crown and one at tip of snout; usually 2 (rarely 1) dorsal pigment spots posteriorly, 1 on tail and 1 just above or slightly posterior to anus, and 1 ventral pigment spot on tail; length 1.57–2.05 mm .... *Urophycis regius*



6A. No pigment above posterior part of gut; yolk pigmented; 2 well-developed broad bands of pigment dorsally between head and anus and 2 on tail, the posteriormost extended into the dorsal and ventral finfolds; length 3.05–3.75 mm .... *Merluccius albidus*

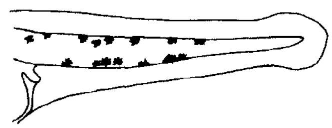


6B. Pigment above posterior part of gut; yolk not pigmented, or slightly so by end of stage; in early stages few pigment spots on body beyond head, these not developed into definite bands; in later stages a single pigment band dorsally on posterior part of head; 2 broad pigment blotches on tail; in early stages both caudal blotches extended into dorsal finfold, the posteriormost also into ventral finfold; length 2.64–4.42 mm .... *Merluccius bilinearis*



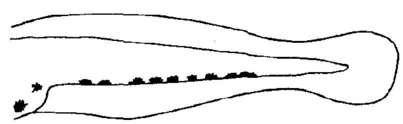
7A. Preanal myomeres 22 or less 8

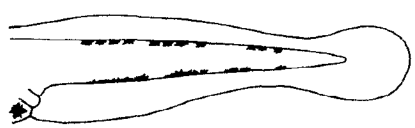
7B. Preanal myomeres 23–25; no pigment on yolk and little or no pigment on gut; pigment on tail initially scattered, ultimately in two bars; no pigment near tip of tail; length 3.2–5.3 mm .... *Pollachius virens*



8A. Pigment present dorsally between back of head and anus, absent on yolk 9

8B. Pigment absent dorsally between back of head and anus, usually present on yolk; pigment in long, continuous or broken bar ventrally on tail, present or absent dorsally; preanal myomeres ca. 14–18; length 4.12–6.45 mm .... *Microgadus tomcod*





9A. Two dorsal and three ventral pigment bands on tail; the posteriormost ventral pigment band near tip of tail; length 3.0–5.19 mm .... *Gadus morhua*

9B. Dorsal surface of tail lacking pigment, ventral surface with continuous row of closely-spaced melanophores; length 2.0–5.5 mm .. *Melanogrammus aeglefinus*

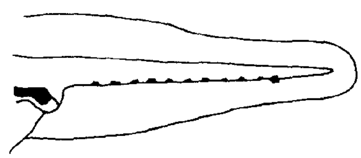


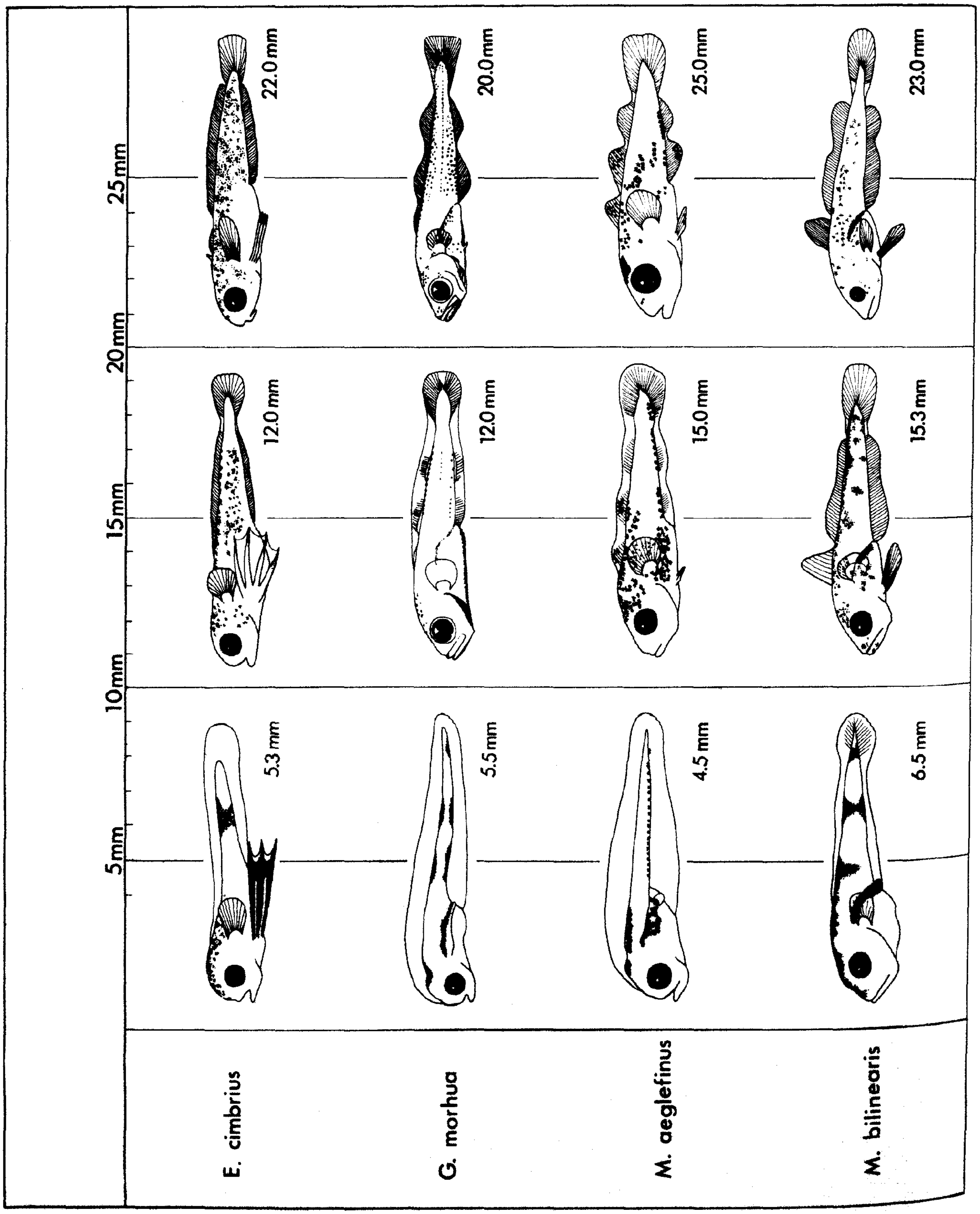
TABLE 5. Eggs of gadoid fishes of the Mid-Atlantic Bight

	Diameter	Oil globule(s)	Color	Ecology	Season
E. cimbrius	0.65–1.25	present, initially many, later coalesced	greenish, yellowish, reddish, blackish, cream, or colorless	pelagic	mid-Feb. to Sept. or Oct. (N. Amer.)
G. morhua	1.0–1.89	absent	cream, green, yellowish red, deep red, or clear	pelagic	year round (N. Amer.)
M. aeglefinus	1.1–1.72	absent	clear	pelagic	Jan. to July (N. Amer.)
M. bilinearis	0.70–1.11	present, single	clear	pelagic	April to Oct.
M. tomcod	1.39–1.7	present or absent, when present several extremely small	clear, yellowish	demersal	Nov. through Feb.
P. virens	1.0–1.22	absent	clear, transparent	pelagic	late Sept. to early March
U. chuss	0.63–0.97	present, initially up to 54, later coalesce to 2 or 3	clear	pelagic	May (or possibly April) to late Sept.
U. regius	0.67–0.81	present, one large and cluster of small	clear	pelagic	Sept. to Feb. or March

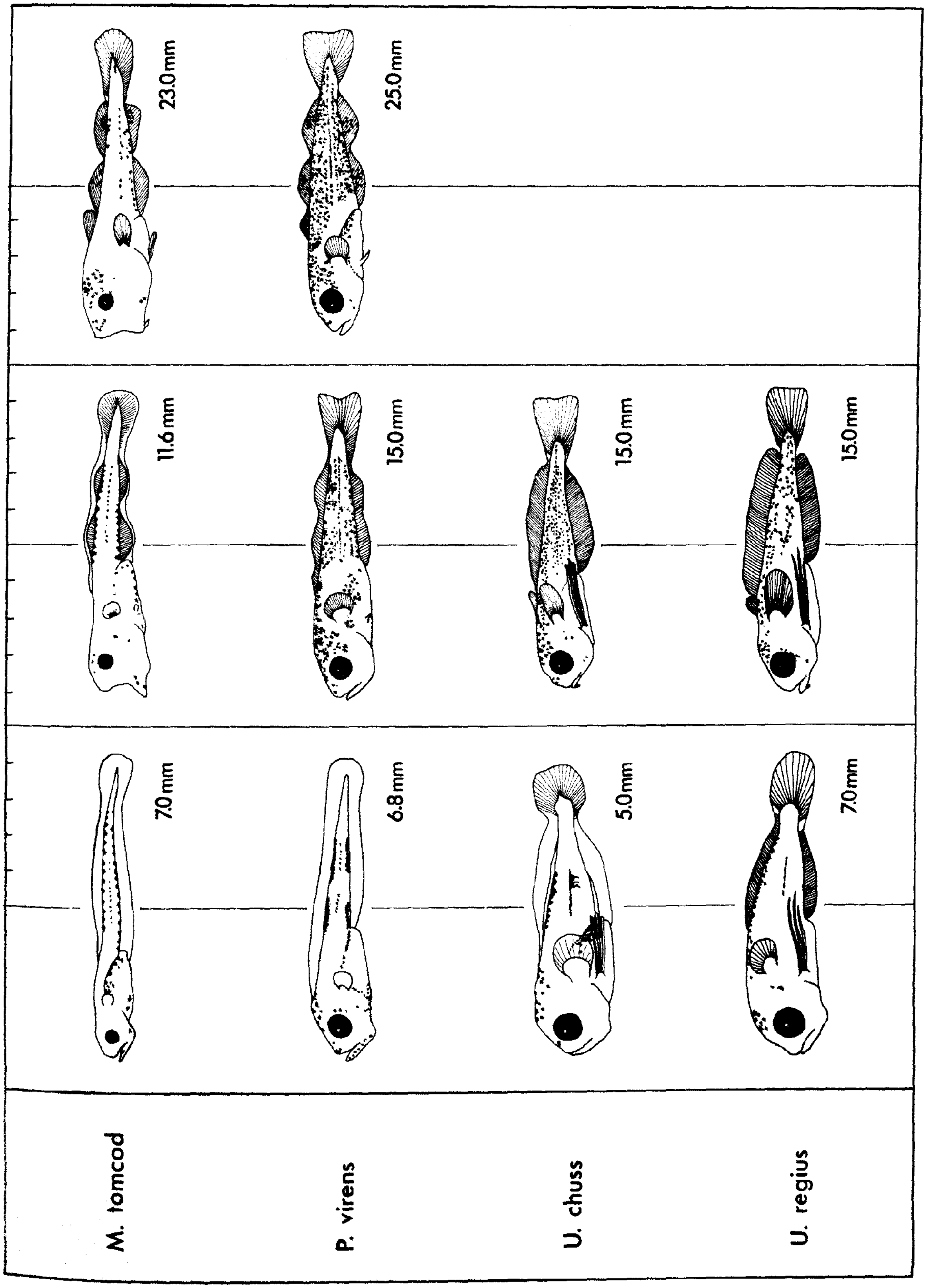
TABLE 6. Vertebrae counts and size ranges of larvae of gadoid fishes of the Mid-Atlantic Bight

	Preanal vertebrae	Postanal vertebrae	Total vertebrae	Size range
E. cimbrius	16	38–39	51–55	2.75–20.0 mm
G. morhua	18–20	32–35	44–57	5.5 –30.0 mm
M. aeglefinus	19–22	32–35	50–57	4.0 –28.0 mm
M. bilinearis	27–28	26–27	54–56	3.5 –22.5 mm
M. albidus	25	26–27	50–56	–
M. tomcod	14–18	–	52–57	7.0 –12.1 mm
P. chesteri	–	–	49	–
P. virens	23–25	29–32	53–57	4.0 –23.0 mm
U. chuss	14–17	33	45–50	2.1 –11.0 mm
U. earlii	14–16	31–32	46–47	–
U. regius	13–14	31–33	45–46	4.0 –15.0 mm
U. tenuis	13–17	42	47–50 56–57(?)	–

Fig. 135 (on next page). Development of larval and early juvenile stages of gadiform fishes of the Mid-Atlantic Bight. Information is lacking for *M. albidus*, *P. chesteri*, *U. earlii*, and *U. tenuis*.



5mm
10mm
15mm
20mm
25mm
E. cimbrius
5.3 mm
12.0 mm
22.0 mm
G. morhua
5.5 mm
12.0 mm
20.0 mm
M. aeglefinus
4.5 mm
15.0 mm
25.0 mm
M. bilinearis
6.5 mm
15.3 mm
23.0 mm



M. tomcod
P. virens
U. chuss
U. regius
7.0 mm
6.8 mm
5.0 mm
7.0 mm
11.6 mm
15.0 mm
15.0 mm
15.0 mm
23.0 mm
25.0 mm

Enchelyopus cimbrius (Linnaeus), Fourbeard rockling

ADULTS

D.$_1$ 1;[8,43] D.$_2$ 45–53;[10] A. 37–45[8,43] (although once reported to 48[45]), in western Atlantic 39–43;[10] C. 30–34;[43] P. 15–17;[8,43] V. 5–7;[10,45] scales 54–55 (but 51–57 according to some authors);[43] gill rakers 9–10; pores in lateral [redacted]

length: Diameter of eye 22.2–24.4.[8] Proportions as times in TL: Depth 7–8.[10] First ray of dorsal nearly equal to head length.[45]

Body slender, tapering from tip of pectorals to caudal peduncle,[10] rounded in front of vent, laterally compressed behind.[45] A pair of long barbels at anterior [redacted] near posterior end of pectorals.[8,43] Caudal and pectorals rounded; pelvics noticeably in front of pectorals.[10,45]

Pigmentation: Reddish, grayish, yellowish, or dusky brown above, paler on sides, and with irregular brown spots on rear of body; sides of head silvery; belly whitish (although also reported as grayish sky blue), dotted with brown; cavity of mouth dark purplish or bluish. First dorsal blackish blue, other unpaired fins grayish blue or ashen gray edged with yellowish or reddish. Second dorsal, anal, and distal parts of caudal lobes with dark spots. Pectoral bluish black, pelvic lighter.[8,10,22,43,45]

Maximum length: Ca. 419 mm,[3,8,32] although this record has been questioned and total length may not exceed ca. 380 mm.[43]

DISTRIBUTION AND ECOLOGY

Range: In the western Atlantic, coastal waters from the Gulf of St. Lawrence (or further northward) to Narragansett Bay, southward generally along the edge of the continental shelf to off Cape Fear, North Carolina.[3,8,43] In the eastern Atlantic, along the coast of Europe northward to the western Barents Sea, eastward to the western Baltic, and occasionally, the Gulf of Finland, and southward around the British Isles to the coast of France in the Bay of Biscay. Also recorded from the Faroes and Iceland, but not known from Greenland.[5,8,14,22,43]

Area distribution: Recorded from off New Jersey,[16] from mouth of Delaware Bay,[29] and from off mouth of Chesapeake Bay.[40]

Habitat and movements: Adults—a bottom dwelling,[8] somewhat solitary species,[21] usually found in relatively shallow water [10] over soft bottoms [3,23,32] of mud,[8,10,30,38] silt,[43] or muddy clay,[12] and, less frequently, sand, gravel, or sand-shell bottoms [10,12] and oyster beds.[30,34] Probably [redacted]

surface at sizes up to 45 mm.[9,11,35,45]

Apparently go to bottom after reduction in size of pelvic fins,[19] at a length of 40–45 mm, and an age of "a few months" [31] (but probably not more than three [45]). Probably remain in shallow water for one or two years, then move out into deeper water.[31]

SPAWNING

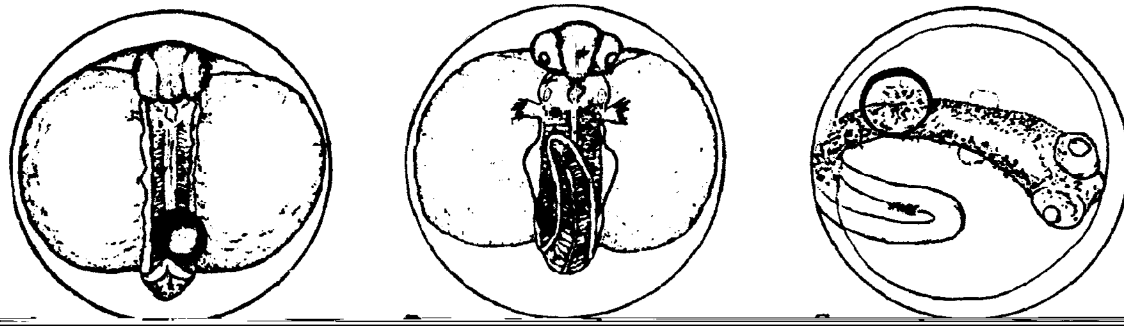
Location: At bottom.[1] Eggs have been observed in the Gulf of Maine [4] and in Narragansett Bay, but eggs in the latter area may have actually been spawned offshore.[44] In European waters spawning occurs "in shallow water near the coast." [5]

Depth: In Gulf of Maine, probably less than 137 m, but may be deeper on the slope.[45] In Europe a ripe female taken at 48 m.[40]

Season: In North American waters, February 10 [12,31] to September [8,26] or October,[10,45] but with peak activity mid-July to mid-August.[1] In New England, February to August.[15,35] In Long Island Sound, February 10 [12] to June 11.[31] Spawning increases with spring high tides associated with new or full moon.[1,10] In European waters January [5,8,28] to November.[13,37] In the North Sea February to August, peak activity in May; [5] in the Baltic January [28] to mid-October,[41] peak in May; [28] in the Gulf of Gdansk first week of May [13] to possibly November, peak June to August, but primarily August.[13,31,37]

Time: Probably at all times, but peak activity during the morning.[1]

Temperature: In Canadian waters normally at 13–19 C.[10] In U.S. waters eggs recorded at 1.15 to 16.10 C, with peak abundance at 6–9 C; [12,31] spawning activity peak, however, apparently at 9–10 C.[31,45] Optimum tempera- [redacted]



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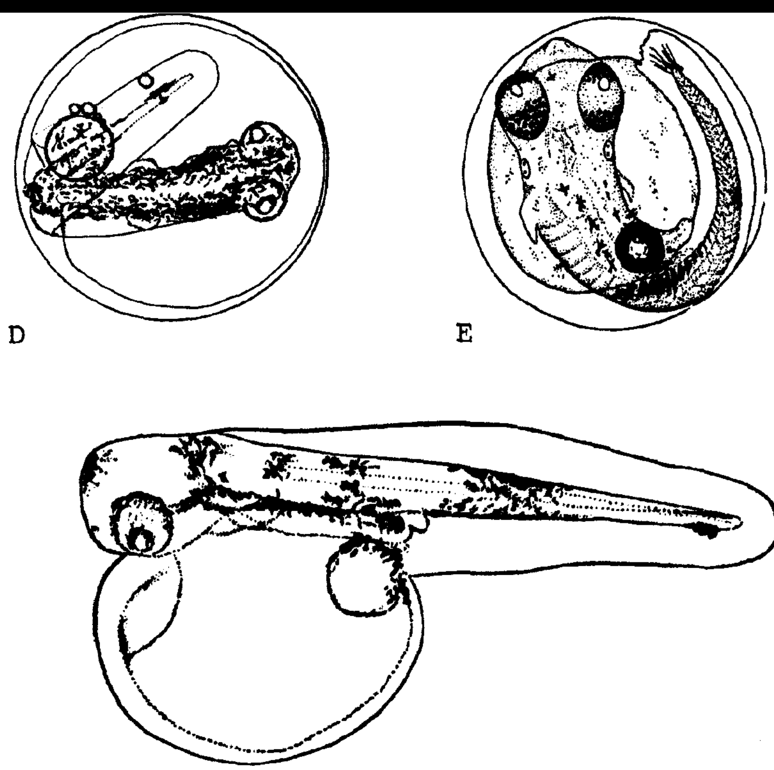


D E

F

Fig. 137. *Enchelyopus cimbrius,* Fourbeard rockling. A. Blastopore closed; somites, pigment forming. B. Otoliths evident, pectoral fins forming. C. A somewhat more advanced embryo, pigment developed on head, body, and tail. D. Pigment on tail well defined. E. Body movements, heartbeat established, eye pigment well-developed. (*A, B, E, Battle, H. I., 1929: figs. 2, 3. C, D, Ehrenbaum, E., and S. Strodtmann, 1904: fig. 4.*)

son.[5,12] In North Sea average 0.90 mm in March, 0.873 mm in April, 0.834–0.827 mm in May, and 0.766–0.743 mm in June.[30] In Baltic 0.97–1.10 ($\bar{x}$ 1.04 mm) in February, 0.82–1.07 ($\bar{x}$ 0.93–0.96 mm) in May, $\bar{x}$ 0.90 in August. Geographic and seasonal variation in egg

[redacted]

oil globule, with sometimes several smaller ones in earliest stages.[42] Largest oil globule ca. 1/5 diameter of yolk.[5,41] Diameter of oil globule 0.13 [10,26] (or possibly as small as 0.08 [15]) to 0.25 mm;[34] average size 0.16 mm.[6,19] Oil globule usually pigmented;[20,42] color

[redacted]

yellow.[26] Perivitelline space narrow (JDH). Ehrenbaum[41] has described an air space which is frequently visible along the exterior of the egg membrane, and "appears in the form of an irregular caul."[34]

EGG DEVELOPMENT

Development at 15 C (Battle series):[26]

8 1/2 hours (Stage A) — 32–64 cell stage, segmentation cavity formed.

11 hours (Stage B) — Blastoderm over 1/4 yolk; germ ring visibly thickened; embryonic shield evident.

14 hours (Stage C) — Blastoderm over 1/2 to 3/4 yolk, embryonic shield considerably lengthened.

17.5 hours (Stage D) — Embryonic shield generally narrowed, more distinct and with a spatulate flattening extended posteriorly to margin of blastopore.

21 hours (Stage E) — Optic vesicles formed; yolk almost surrounded by blastoderm.

36 hours (Stage F) — Closure of blastopore; oil globule located posteriorly just under caudal prominence; optic vesicles more distinct; alar membrane, some somites formed; heart forming; scattered melanophores on ventral surface.

51 hours (Stage G) — Body elongate, pressed into surface of yolk; tail elongate; pectoral fins outlined; heart chambers, auditory vesicles, otoliths, and lenses formed; additional melanophores on body; eye pigmented.

72 hours (Stage H) — Yolk decreased; finfold formed; pectorals clearly defined; 2–3 branchial

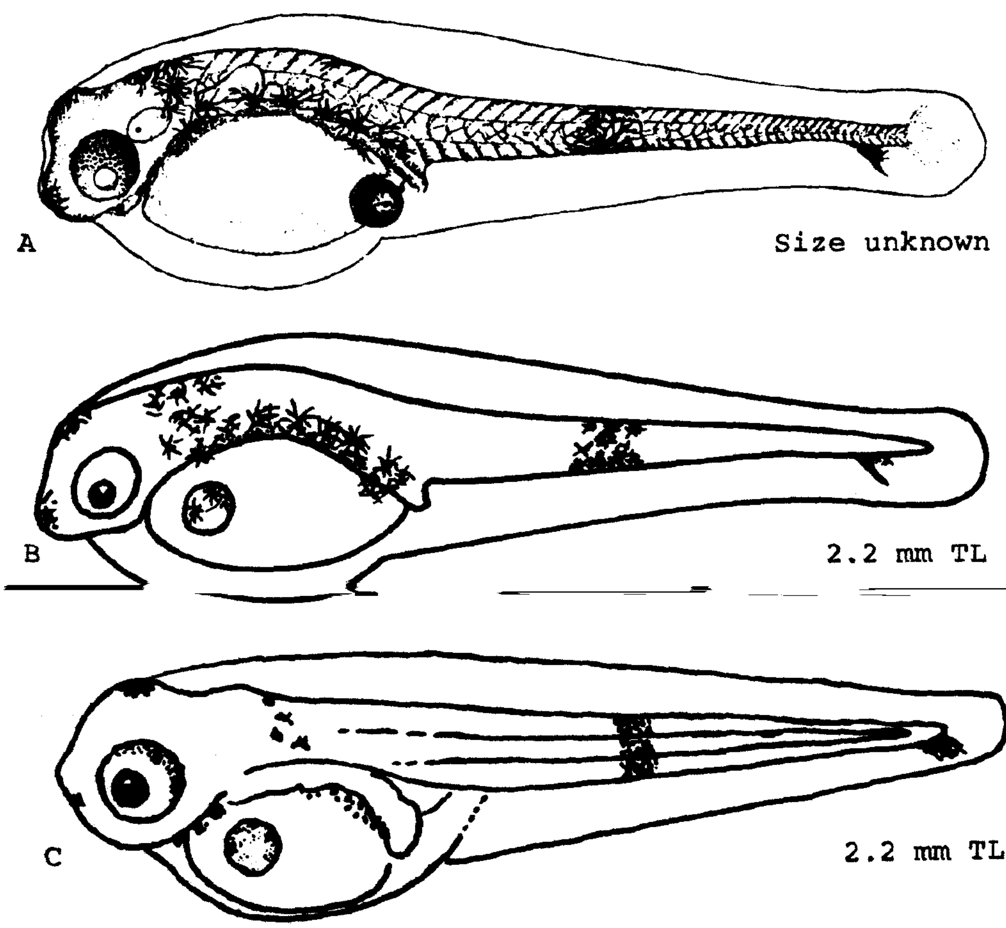
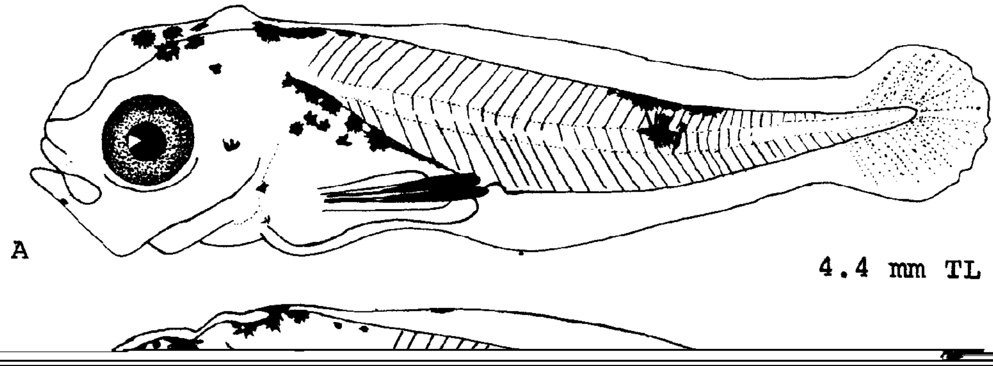


Fig. 138. *Enchelyopus cimbrius*, Fourbeard rockling. A. Yolk-sac larva, size unknown, pigment in eye well-developed. B. Yolk-sac larva, 2.2 mm TL. C. Yolk-sac larva, 2.2 mm TL. (*A, Battle, H. I., 1929: fig. 3. B, Colton, J. B., Jr., and R. R. Marak, 1969: 14. C. Miller, D., 1958: unnumbered.*)

clefts formed; movements evident;

Development at 13 C (Battle series);[1] identical to devel-


A
4.4 mm TL

Comments on development: Pigment appears first on oil globule; [5] may also develop on yolk, but this is not typical of all populations.[42] In advanced embryo two pigment patches on tail; one at midpoint, one at tip.[41]

Incubation period: At 13 C, average 5.4 days; at 15 C, average 4.5 days.[1]

Incubation temperature: Normal development 13–19 C; [1,8,44] hatch abnormally at extremes of 5.0 and 24 C; [26] found in nature at minimum of 0.4 C, but probably not developing.[16]

Incubation salinity: Normal development at 18.6–45.0 ppt, abnormal development at extremes of 5.6 and 80.0 ppt (author notes that larvae hatched at high salinity are distinctly smaller than those hatched at low salinity).[26]

YOLK-SAC LARVAE

Minimum length reported, 1.63 mm; maximum hatching length, ca. 2.42 mm,[6] average hatching length, 2.03 mm; [6,17,20] length at end of stage 2.75–3.0 mm.[5]

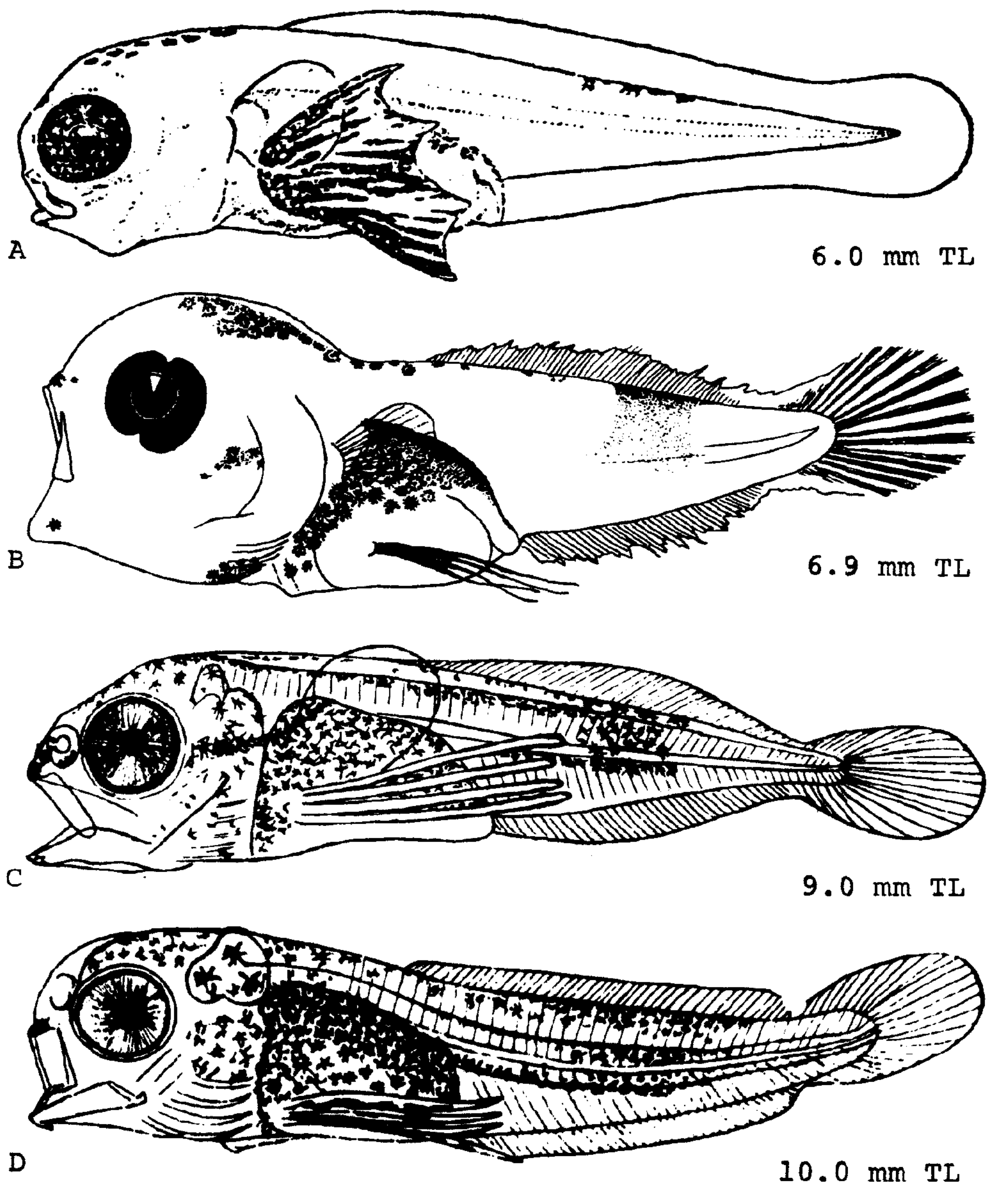
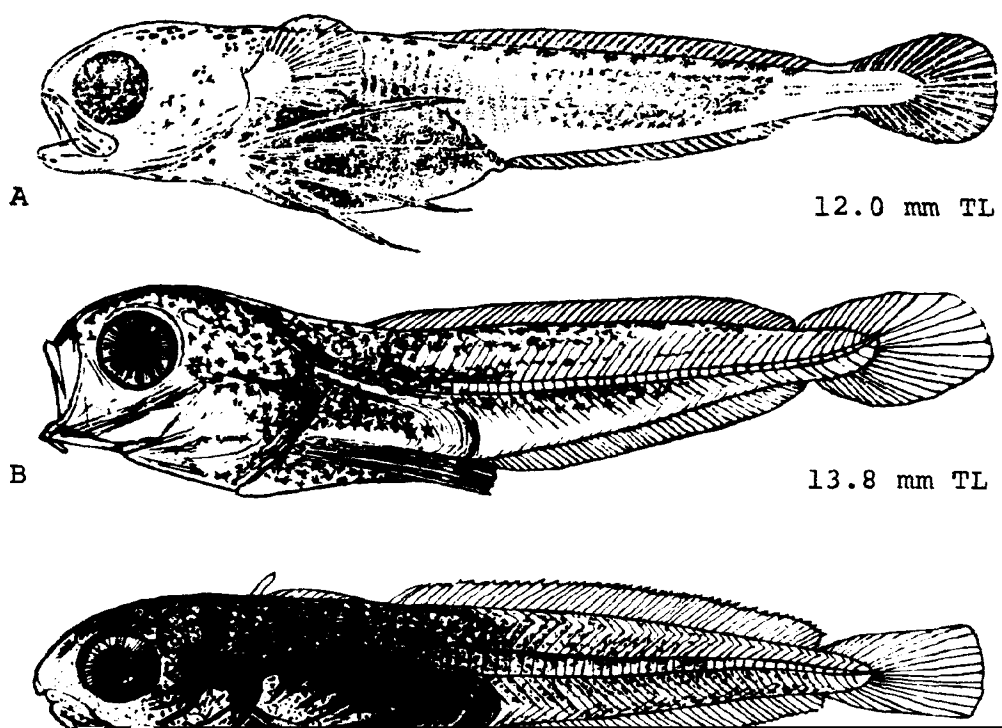


Fig. 141. *Enchelyopus cimbrius*, Fourbeard rockling. A. Larva, 6.0 mm TL. B. Larva, 6.9 mm TL. C. Larva, 9.0 mm TL. D. Larva, 10.0 mm TL, barbel evident. (*A, Rass, T. S., 1949: fig. 22. B, Colton, J. B., Jr., and R. R. Marak, 1969: 14. C, D, Ehrenbaum, E., 1908: fig. 1.*)



[redacted]

Fig. 142. *Enchelyopus cimbrius*, Fourbeard rockling. A. Larva, 12.0 mm TL. B. Larva, 13.8 mm TL. C. Prejuvenile, 17.5 mm TL. (*A, Rass, T. S., 1949: fig. 22. B, Ehrenbaum, E., 1908: fig. 1. C, Ehrenbaum, E., 1909: fig. 101, after Brook, G., 1891: pl. 6.*)

[redacted]

Postanal crossband evident up to 10 mm.[3,20,39] At 9.0 mm pigment spot on ventral surface near tip of tail present[34] or absent;[6] entire ventral outline and, usually, tip of tail free of pigment; gut and eyes with bluish sheen. At 8.0 to 10.0 mm silvery pigment developing on gut and gill covers. At 10 mm dorsal and mediolateral postanal pigment greatly increased.[30,34] Eyes brilliant iridescent blue-black.[26]

PREJUVENILES

Size range, ca. 16 (but evidence based on color)[41]–ca. 32 mm.

Snout barbel evident as faint tubercle at 20 mm[19]–22 mm,[34] well-developed at 30 mm.[19]

At 22 mm pelvic decreased in relative size, not quite reaching anus.[34]

Pigmentation: At 16–18 mm green and silvery;[41] at 17–22 mm shiny silvery;[3,5,34] at ca. 27 mm pigment along back distinctly mottled;[11] at sizes up to ca. 32 mm ventral surface brilliant silver, gradually shading to greenish black toward dorsum.[19]

JUVENILES

Minimum size described, 37.7 mm.

Pelvics considerably shorter than in earlier stages relative to body length.[46]

Pigmentation: Similar to previous stages, but with generally increased dark pigment.[46]

AGE AND SIZE AT MATURITY

Minimum length at maturity, females 150 mm,[40] males unknown.

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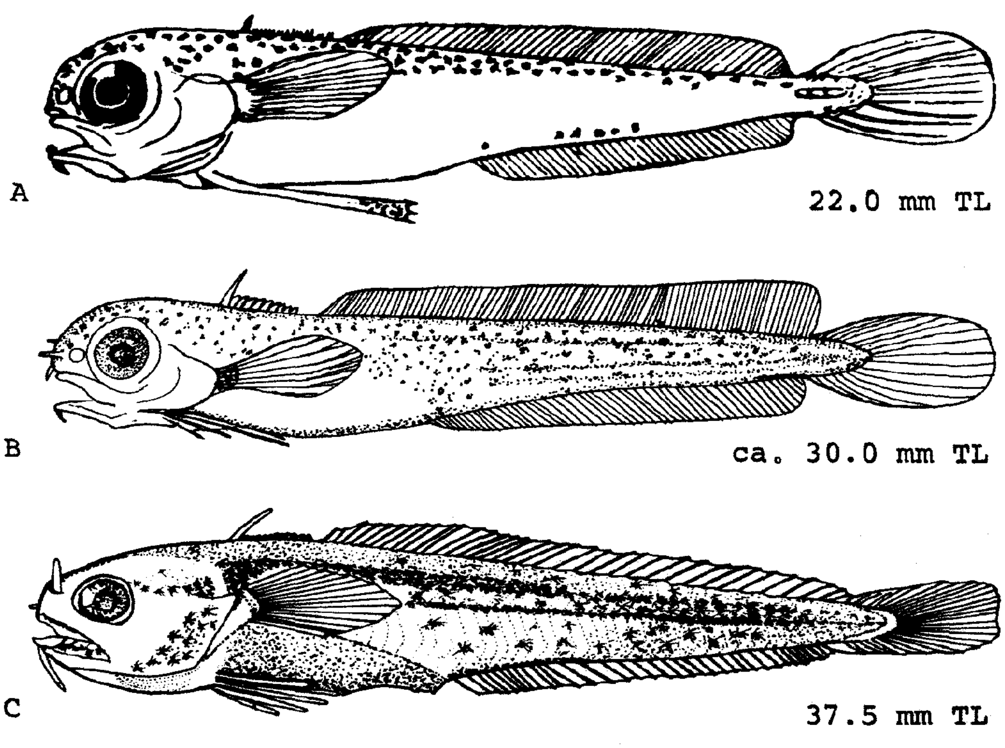

Fig. 143. *Enchelyopus cimbrius*, Fourbeard rockling. A. Prejuvenile, 22.0 mm TL. B. Prejuvenile, ca. 30.0 mm TL. C. Juvenile, 37.5 mm TL. (*A, Ehrenbaum, E., 1908: fig. 1. B, Brook, G., 1891: pl. 6, Tamiko Karr, delineator. C, Original drawing, Nancy Schenk Smith.*)

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Gadus morhua Linnaeus, Atlantic cod

ADULTS

D.$_1$ 12–16 [35] (w. Atlantic 13–16 [41]), D.$_2$ 14 [215]–26 [204] (w. Atlantic 16–25 [215]), D.$_3$ 15–21 [35] (w. Atlantic 18–21 [240]); A.$_1$ 17–25 [35] (w. Atlantic 20–24 [71]), A.$_2$ 15–23 [35] (w. Atlantic 17–22 [41]); scales 150–170; [71] total gill rakers outer row first arch 18–28; [35] vertebrae 44 [27]–57,[174] but lower values may reflect growth in rearing ponds; [27] otherwise minimum vertebrae 49; [35] trunk vertebrae 18–20; caudal vertebrae 32–35.[211]

Proportions as times in TL: Depth 4.74–5.15, head 3.53–3.76.[71] Diameter of eye as percent HL: 15.5–23.6.[35]

jaw somewhat enlarged. Lateral line distinct, arched in forward two-thirds.[41] Scales very small, cycloid.[71] Caudal fin slightly concave; [41] pelvics inserted slightly in front of pectorals; [240] 2nd pelvic ray slightly extended and filamentous.[41]

Pigmentation: Color highly variable, with individual fish able to rapidly change color, shading, and pattern.[218] Two main color groups: gray-green and red [240] (with red fish restricted to shoaler waters [96]). Fish in the gray-green group may be almost black, sooty or brownish gray, oil gray, olive brown, mouse gray, ash gray, clay-colored, greenish, pale pearly, or yellow on the sides; "red" fish may be irregularly blotched with creamy white and orange; [39] others are almost black above with light gray-green mottled bars.[42] Fins usually same shade as ground color; [71,240] vertical fins sometimes with dark spots arranged in transverse rows,[35] or, rarely, marked with white, orange, dull red, or greenish black streaks.[41] Lateral line always pale, never dark.[240,253] Peritoneum steel-gray,[173] silvery leaden or leadened black,[35] and with white dots.[41] Iris dark.[39]

Maximum length: Recorded to 1800 mm,[35] although pos- [redacted]

feeding shoals may strand on beaches while pursuing prey close inshore.[232,240] Large concentrations of cod have been reported at surface associated with drift ice.[193]

Although recorded from depths of up to 600 m,[16,17,35,71,259] prefer depths of ca. 40 to 130 m,[96] and, in some areas at least, most concentrated between 15 and 75 m; [241,246] minimum depth ca. 0.66 to 1.0 m.[80,246] Cod have been found at surface over depths of 2000 m,[193] and may concentrate at one particular depth in deep water, as at 460 m in water over 1000 m deep.[252] In Canadian wa- [redacted] to 40 km) in autumn and early winter and return shoreward in spring and early summer; others make orderly extended migrations to offshore banks or southward along the coast in autumn and early winter; still others are "rover fish" and move at random (but most typically northeastward along the coast) at about 200 km a year.[217] Regular annual movements are highly variable in different localities. In New Brunswick, Canada there is an inshore "run" in June, while in New England cod move to offshore banks in summer. Such differences may involve preferred water temperature,[14,146,219] thus, small cod in east Newfoundland move from deep to shoal water in spring, but larger cod remain in deep water (at depths of 200 m or more) below the cold water layer.[16] Labrador cod move north and south, always remaining in cold water.[41] There is apparently some intermingling of various populations as a result of general movements.[164]

beaches,[219] in very shallow water on muddy ground among weeds,[161] and in association with jellyfish.[84,121,213,214] "Young" ca. 12 mm long at surface near Woods Hole, Massachusetts.[222] Larvae ca. 3–8 days old positively phototaxic, but are repelled by and die if exposed to very strong light.[6,36,113] Specimens ca. 3 [205]–12 mm long from surface [17,222] to 75 m.[10] Depth varies with size of larvae, time of day, and possibly, location: thus larvae 3.0–5.0 mm at 0–30 m; 3.5–8.0 mm at 0 to 20 m; [205] 5–8 mm at ca. 10–41 m, but mostly at 15.5 m.[53] Larvae of unspecified size variously recorded as from 18–23 m; [6] 20 m and up diminishing toward surface; [58] most common at 40–75 m; [19] and mostly at 10–30 m.[47] Larvae also recorded from "intermediate water layers" where salinity is not sufficient to keep them afloat.[186] Occasionally at less than 10 ppt, but occurrence probably accidental [150,205] (survival at these salinities is questionable, [illegible] coastal water.[218] Specimens 70 to 100 mm long are "somewhat phototaxic."[119] Individuals ca. 35 to 50 mm long are reported to hang obliquely in water with head downward against the current.[159,271] Specimens 25[214] to 300 mm[238] have variously been recorded from ca. 5[134,181,214] to 366 m;[238] but depth varies from place to place and from season to season.[250] Specimens 100 to 300 mm recorded at 183 to 366 m in the northern North Sea, but in conspicuously more shallow water in the southern North Sea.[240] Various length/depth relationships are as follows: specimens 63–93 mm in 38 m (Nantucket);[201] at 75 to 100 mm inshore, but also at depths of 36 to 100 m (Scotland);[161] at 100 to 190 mm as shoal as 5 m (Norwegian Sea); at ca. 150 to 175 mm in 15 to 22 m; at ca. 300 mm in 55 m (Lofoten Islands);[138] at 300 to 600 mm at 128 to 238 m (Norwegian Sea).[182] Most "fry" are at an average depth of ca. 35 m, with a variation of 8 to 42 m;[118] while one year olds have been caught at depths of 73 and 274 m.[196] Specimens ca. 95 mm long, 193 km offshore.[153,163] Juveniles taken at less than 31.3 to 35.0 ppt, and through temperature range of 6–20 C[52] (but specimens 140 to 210 mm recorded at −1.4 C).[265] Small cod are apparently able to survive higher temperatures than larger cod.[216,240]

In Mid-Atlantic Bight descent to bottom at 25–50 mm[217,232] in New England at age of 2 months and size of ca. 25 to 40 mm.[17,240] In North Sea at age of ca. 2 1/2 to 4 months,[108,194,252] descending in relatively shallow water[84,163] during May,[211] and early July[154] (and remaining pelagic for a longer period in southern waters[158]) at extreme lengths of ca. 20 to 50 mm (but usually 25 to 40 mm).[32,163,214] In Norwegian Sea sometimes remain pelagic for up to 7 months,[257] and to sizes of 90 to 95 mm.[163,240] In Barents Sea descend by late summer[273] (August and September[54]) at lengths of 25 to ca. 75 mm.[10] In or near Iceland descend in early August at ca. 45[54] to 90 mm.[158] In Greenland mid-August and September at ca. 25 to 30 mm.[54,131] In Faroes descend in July.[211] In the Baltic move to shallow water (shores and river mouths) at 40 to 50 mm.[120,130] Young cod may descend both in the littoral region and at greater depths.[181] Not all juveniles go to bottom in coastal waters; some descend on offshore banks.[240] Two factors affect the length of "larval" life: water temperatures and the depth to which the young must descend.[54] It is possible that 0- and 1-year class fish make seasonal migrations to shallow water during summer, returning to deeper water in winter, but there is no direct evidence to support this.[252] Some populations may make short movements from sandy, muddy bottoms to rough areas,[39] while others remain more or less stationary for several years[173,251] or up to the time of maturity.[172,196] In still other populations various movements take place: in Norway two year old fish move out into [redacted]

(although some two year olds may not return inshore until the 3rd or 4th year[277]); in Barents Sea juveniles are in shallow feeding grounds from June to September, but move into deeper water along edge of shelf during winter. The extent of the annual inshore-offshore migration in the Barents Sea increases with increasing age, so that juveniles eventually make "dummy runs" toward the spawning grounds and spend winter near spawning adults. In Iceland older juveniles actually accompany adults on the spawning runs.[115,252,259,267] "Young" apparently move from the nursery areas in Lofoten Banks to the Barents Sea,[65] and from the Barents Sea make feeding excursions to Sweden.[41] In Nova Scotia, inshore cod move progressively farther offshore with age; in southern Canada smaller cod are typically in more shallow water than larger cod.[205] Juvenile movements are not well-known in American waters; however, in Massachusetts leave coast by mid-June at sizes of ca. 75 to 100 mm.[51]

SPAWNING

Location: In Europe principal spawning grounds along coast of Norway (Lofoten Islands), Barents Sea, North Sea, and Faroes to north of Bear Island and possibly Novaya Zemlya;[35,46,81,84,231,273] also the Baltic Sea,[214] around Greenland,[35] and Iceland.[58] On the North American coast Newfoundland Banks[214] south to at least New Jersey[240] and, possibly, to North Carolina.[253]

Spawning occurs in inlets,[6,35,217] fjords[58,63,70,87,131] bays,[10,232] and harbors,[6,49] and on both coastal and offshore banks[153,211] over bottoms of rock, clay, sand, mud, or stone, as well as over areas of aquatic vegetation;[6,35,75,138] sometimes under ice.[35] Spawning fish may occur primarily in a narrow "transition zone" (thermocline, halocline) which may shift position from midwater to near bottom.[28,54,83,97,257] Maximum distance out, 273 km.[277]

Depth: In water 1.5 (White Sea) to 330 m deep (Hamilton Bank)[266] and highly variable on both sides of the Atlantic (although along coast of United States usually shoaler than ca. 73 m).[240] Optimum depth over entire range estimated from 40 to 136 m.[18,32,92,122,163] Depth may vary with season: in North Sea begins in December within the 40 m depth contour, in January extends out to 80 m, and in March to 200 m.[206]

Season: Considering the range as a whole, apparently spawns throughout year in both the northwestern and northeastern Atlantic (JDH). In American waters peaks occur from January to mid-September[33,41,109,208,217,252,277] and in November,[200] varying greatly from year to year and from locality to locality.[201] In European waters peaks vary from February to mid-September[32,68,104,107, [redacted]

TABLE 7. Spawning season of western Atlantic *Gadus morhua*.

	J	F	M	A	M	J	J	A	S	O	N	D
Nova Scotia [40,49,208,240]			X			X	X		X	X	X	X
Bay of Fundy [49,208]	X	X	X	X	X							
Gulf of St. Lawrence [2,208,218,276]					X	X	X		X	X	X	
Labrador [126,143,269]			X	X	X	X	X	X				
Newfoundland [8,30,164,198,252]			X	X	X	X	X	X	X	X	X	
Emerald Island [208]			X	X								
Grand Bank [41,171,240]				X	X	X	X	X				
Banquereau [208,257]				X	X	X						
Sable Island [208,218]			X	X								
Browns Bank [208]					X							
New England (no specific location) [91,182,196,240]	X	X	X	X	X	X			X	X	X	
Gulf of Maine [33,109]	X	X	X	X								
Maine [240]		X	X	X	X							
Georges Bank [203,218,240]	X											X
Massachusetts [144,171,201,222,240]	X	X	X	X		X			X	X	X	X
Rhode Island [77,144,171]	X	X	X	X	X						X	X
New York and New Jersey [240]	X	X										X
North Carolina [253]	X	X	X	X	X	X			X	X	X	X

year[157] depending on temperature.[104,226] On New England coast "smaller race of cod" spawns from November to April while larger cod begin in July.[196] For seasonal summary see table 7.

Duration: Total spawning period varies in length from place to place. Thus, on Lofoten Banks ca. 84 days[65] and in Arcto-Norwegian region 20 to 50 days.[81] A single individual may continue to spawn over a period of 6 to 8 weeks[9,65,96,277] and a captive specimen was observed to spawn 6 times in a 17 day period.[252]

Time: Primarily at night,[29,276] and possibly crepuscular (thus "dusk and early morning";[11] "probably around day break";[169] and between 1815 and 2300 hours); also recorded at 1130 hours in experimental tanks,[56,245] and eggs extruded but not fertilized on "bright sunny afternoons."[34]

Temperature: Range, -1.1 C[240] (or possibly as low as -1.5 C[269]) to 12.0 C.[186,217] In northwestern Atlantic, 0.6–12.0 C (although higher temperatures are based on indirect evidence); in northeastern Atlantic, ca. 0 C–6.5 C.[186] Spawning can apparently occur on either a falling or rising temperature,[114] although sudden drop in temperature may bring about a cessation of spawning.[6] Spawning fish may be associated with a narrow temperature band within the water column, and the temperature within this band may vary from 3.0 to 6.5 C.[28,54,195,259]

Salinity: Range 10.0 to 35.5 ppt;[10,18,35,45,48,57,68,218] typically somewhat lower in American than in European waters (except for Baltic populations);[186] optimum 32.6[240] to 35.0 ppt[18,122] (although optimums are obviously considerably less in areas such as the Baltic where total range extends from ca. 10.0 to 18.0 ppt).[35] Under experimental conditions complete egg mortality occurred at 9.93 ppt and high mortality at 12.47 ppt.[186] Sperm became immotile at 7.52 ppt.[139]

Behavior: Males usually proceed females to spawning grounds,[57,75] but in some areas, as at Lofoten Bank, large females arrive first.[252] Males set up and defend territories several weeks prior to spawning[261] and remain on spawning grounds longer than females.[249] There is a cessation of feeding during the spawning period.[45] Behavior leading to spawning involves vertical movements, territoriality of males, and, possibly, stratification, with a group of active males above a less vigorous group of males and females.[245] In spite of reports of spawning at the bottom,[96] the actual spawning act apparently takes place at or near the surface[8,15,79] (one author reports spawning within the upper one meter).[196]

Jones stated that, once mature, cod spawn every year until they die, and pointed out that the theory that older cod do not spawn every year was based on erroneously interpreted otolith studies.[252] Thurrow, however, noted that about 7% of all females which developed sexually in a former year were found to suspend propagation for one year.[249]

Fecundity: Total 200,000 to 12,000,000[24] with averages estimated at 94,000,[73] 1,000,000,[270] and 3,000,000 to 5,000,000.[183] Total fecundity increases with weight[129] and length (thus 200,000 at 510 mm, 12,000,000 at 1400 mm).[24] Not all eggs ripen at once[17] and at least 3, and possibly up to 8, batches of eggs are produced each season[23] (Chrzan's statement that mature females "expell their eggs at once and then leave the spawning area,"[229] is probably erroneous, RRM). Estimates of the number of eggs that can be obtained from stripping varies from 11,000 to 3,000,000.[33,133,138,182]

EGGS

Location: Found in bays,[78] inner parts of fjords[176] and in open ocean; in water a few to 2200 m deep[269] (although few beyond the 1000 m depth contour and mostly within the 100 m contour);[211] in Norway most plentiful over 90 m contour,[255] in Newfoundland Bank over 150 to 200 m, and in Labrador over 280 to 350 m.[183] May reach concentrations as high as 4500 per square m of surface in some areas.[10] Initially at or near surface,[2,6] floating slowly upward immediately after extrusion[11,17] (sometimes as slowly as 32 mm per minute[169,277]) but great variation in position in water column occurs;[6] sometimes (as in Langelandsbelt) more numerous on bottom.[155] Sink with age and may actually develop on bottom[3,17,40,73,230] with descent beginning 5 to 10 days after fertilization[111,124,133] (unfertilized eggs sink after maximum of 18 to 36 hours).[196] Changes in position in water column may be influenced by water movement,[205] weight of accumulated debris, or actual changes in specific gravity of eggs.[184] There are geographic differences in depth at which majority of eggs are found (in Norway at 25 to 30 m,[123,128] in Baltic at 100 to 300 m,[35] in Georges Bank, Gulf of Maine in upper 10 m)[82,236] and, apparently, in minimum salinity in which they float (estimates vary from ca. 25 ppt in ocean water[195] to 10 to 14 ppt in Baltic[139,190,191,214]). Other authors have pointed out that eggs will not float at specific gravities of less than 0.025 to 0.021,[56,58,111,205] and that spring freshets cause eggs to sink.[240]

High mortalities may be associated with storms and result from mechanical injury of chorion,[123,266,272,] and large numbers of eggs are sometimes washed ashore and stranded by tides, breakers, and wind.[91,96,138,241]

Ovarian eggs: Initially minute, clear, yolkless. At 0.3 mm yolk formation begins (eggs possibly opaque at this stage[231] and with finely granular yolk[69]); at 0.5 mm yolk evident in all eggs. At a later stage, 2 size groups evident, some 0.8 to 0.9 mm, and others ca. 1.2 mm (with the later group perfectly clear). Size of ripe eggs estimated at 1.0 to 1.8 mm.[23,40,46,69] Eggs ready for deposition are completely transparent[177] (although one author states that they have a "milky appearance"[169]). Micropyle single,[9] evident as a circular disc of yellow with somewhat raised edges[69] in lower hemisphere of eggs.[11,169]

Fertilized eggs: Spherical[5] or nearly so;[194] sometimes distinctly ellipsoidal[114] (perhaps abnormal when so shaped, RRM). Color variable (so much that Dannevig proposed races of cod based on color of spawn):[134] Clear, cream color,[120,183] pale green,[17,96] yellowish red,[256] or deep red (although red eggs usually die in 4 to 5 days).[96] Blastodisc light terra-cotta, but pigment lost as development proceeds.[243] Diameter of egg variously estimated from 1.1 to 1.89 mm;[5,10,17,20,32,33,41,71,72,78,109,195,197,214,243,247] average diameters estimated from 1.30 to 1.76 mm.[14,33,66,109,156,196,277] Eggs are larger in cold water than warm water[240] and size varies seasonally;[156] in Barents Sea 1.49 to 1.53 mm in March, 1.39 to 1.46 in April; in North Sea average decreases from 1.46 mm in early January to 1.30 mm by end of April;[214] in Nova Scotia 1.12 to 1.55 mm in autumn (average 1.36 mm), 1.3 to 1.7 mm in winter and early spring (average in spring 1.50 mm);[6] [redacted]

atypical, RRM). Egg membrane thin,[261] fragile[32] (0.00635[114] to 0.0079 mm thick[159]), laminated,[243] non-iridescent[78,155] (although showing faint bluish translucency[114]). Sars claimed that the chorion consisted of 4 layers;[69] while Ryder pointed out that cod eggs lack a zona radiata.[44] Yolk homogenous, variously described as clear, cream-colored,[214] or yellow,[78,155,247] and surrounded by a thin, fragile vitelline membrane.[127] Oil globules lacking[72,240] (although Sars noted numerous small "oil globules" scattered over the yolk of eggs in which the micropyle was still evident when viewed "with the aid of a strong microscope"[69]). Perivitelline space quite narrow.[127]

EGG DEVELOPMENT

Development at 5.5 C (Meek series):[29]

1st day.	Early cleavage stages.
2nd day.	Blastomeres crowded.
3rd day.	Blastocoel, endoderm, and mesoderm formed, notochord evident.
4th day.	Germ ring around 1/2 yolk.
5th day.	Blastopore narrow; somites, optic vesicles, optic cavity, and infundibulum formed.
6th day.	Blastopore closed; heart, liver, lumen of brain, auditory placodes, Kupffer's vesicles formed.
7th day.	Tail free, median finfold evident; lens separated from ectoderm, nasal organs evident as thickened cellular masses; notochord vacuolated; pronephros formed or forming.
8th day.	Optic nerves forming, small cavity evident in each nasal thickening, heartbeat established.
9th day.	Tail extended nearly to head, body flattened posteriorly, pronephric ducts joined above anus.
10th day.	Embryo fully encircles yolk, gas bladder evident, pectoral fins forming, renal vesicles formed, blood corpuscles evident.
11th day.	Mouth closed by thin membrane, renal vesicles now in contact with cloaca.
12th day.	Hatching.[29]

Development from time of 2-cell stage at 6 C (Bonnet series):[124]

52 hours.	Early gastrula.
62 hours.	Quarter gastrula.

[redacted]

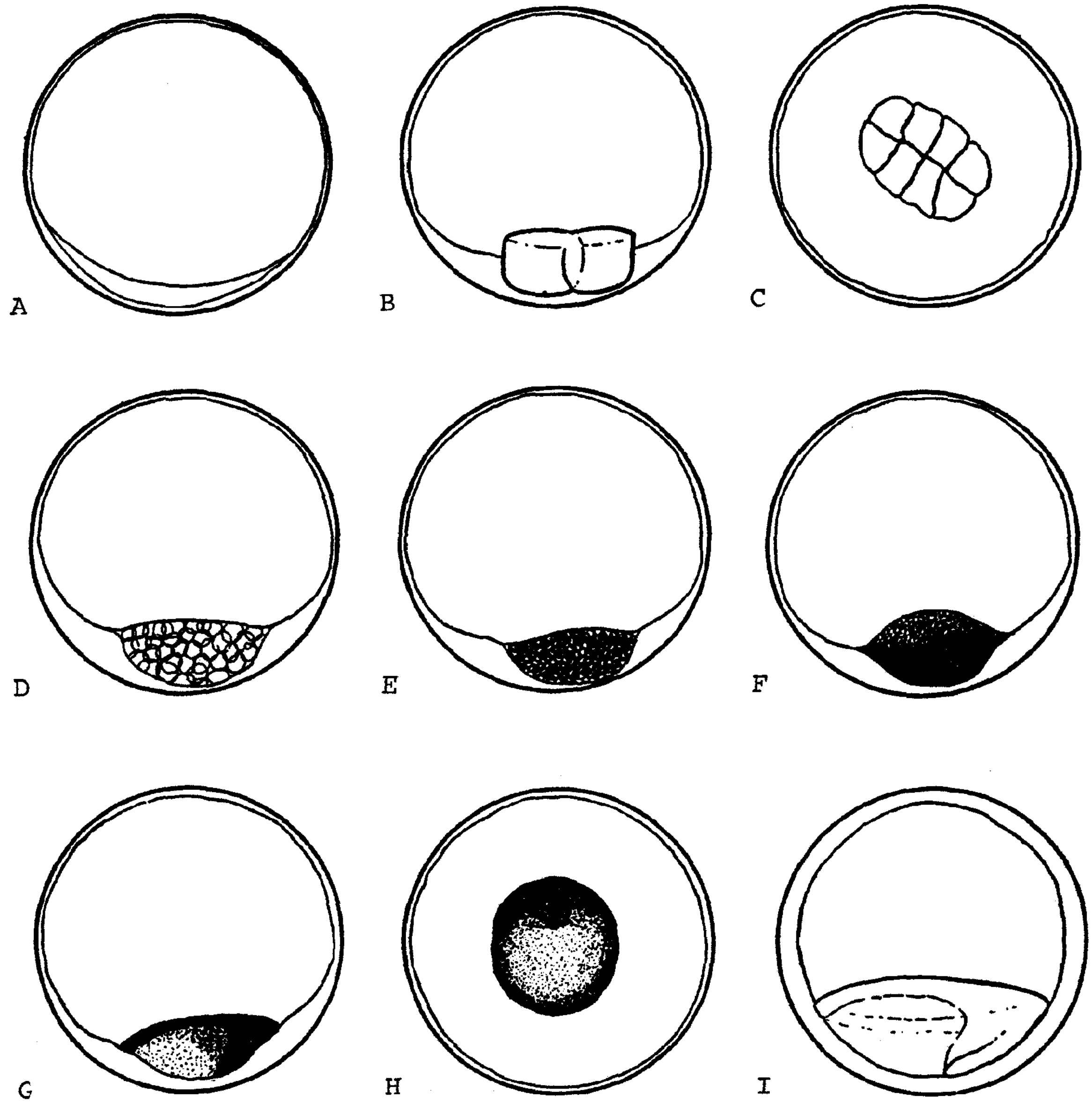


Fig. 145. *Gadus morhua,* Atlantic cod. A. Blastodisc formed. B. 2-cell stage. C. 8-cell stage. D. Early morula. E. Mid-morula. F. Late morula. G. Early gastrula. H. Dorsal view of G. I. Blastoderm extended one fourth over yolk. (*A-I, Bonnet, D. D., 1939: figs. 1–8.*)

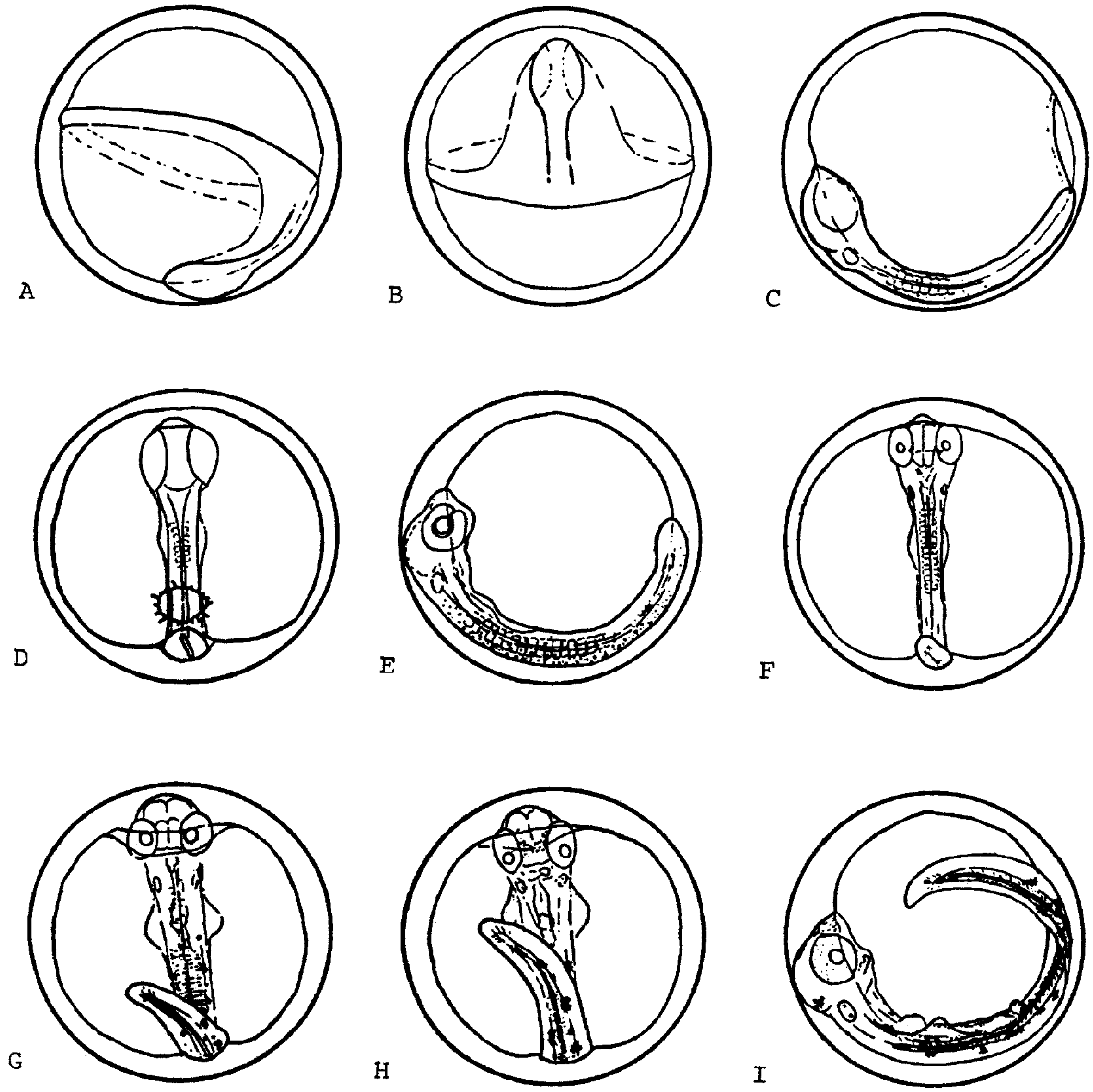


Fig. 146. *Gadus morhua,* Atlantic cod. A. Blastoderm to equator of yolk, lateral view. B. Same as A, dorsal view. C. Blastopore evident, 7 somites formed, pigment developing. D. 11-somite stage. E. 18-somite stage, pigment increased. F. Same as E, pectoral fin buds evident. G. Tail free, 35 somites. H. Heartbeat established. I. Same as H, otoliths developed. (*A-I, Bonnet, D. D., 1939: figs. 9–14.*)

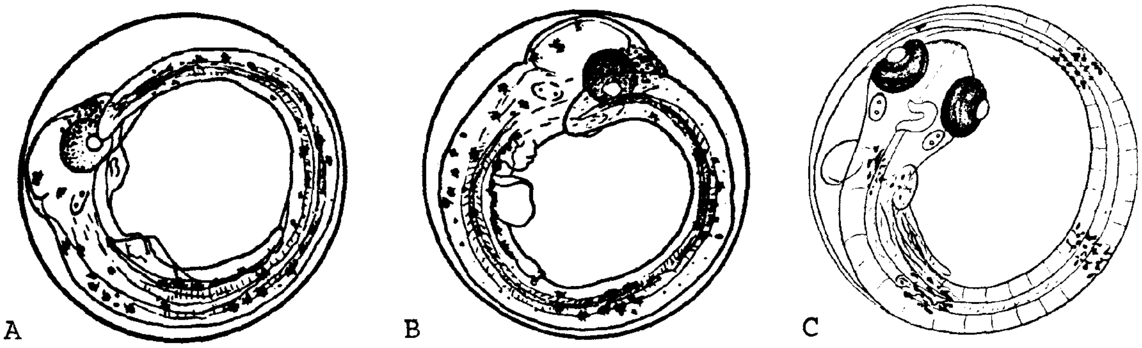


Fig. 147. *Gadus morhua,* Atlantic cod. A. Tail extended to head, pigment developed in upper part of eye. B. Pre-hatching stage, eye well pigmented, body pigment localized into bands. C. Pre-hatching stage showing more definite pigment bands. (*A, B, Bonnet, D. D., 1939: figs. 17–18. C, Ehrenbaum, E., 1905–1909: 226.*)

154 hours.	Pigment evident; 18 somites, pectoral buds formed.
202 hours.	35 somites.
226 hours.	Heartbeat, tail movements established; otoliths evident; eye pigment forming.
298 hours.	Upper eyes well pigmented.
416 hours.	Pigment localized into definite bands, hatching imminent.[124]

Development at 6–8 C (Nordahl series): [274]

Ca. 105 hours.	Blastopore nearly closed, 8–10 somites, notochord formed, future gut evident in posterior half of embryo.
Ca. 111 hours.	13 somites, Kupffer's vesicle forming.
Ca. 120 hours.	Blastopore usually closed, 12–14

Day 3, 1600 hours.	Otoliths evident, pectoral buds forming.
Day 4, 1500 hours.	Heartbeat, body movements established.
Day 5.	Yolk decreased, pectorals pointed posteriorly, liver evident, round melanophores on head and dorsolateral region of trunk.
Day 6.	Eyes pigmented, 3 branchial clefts, nasal pits visible, some individuals hatching.
Day 7.	Some individuals not yet hatched. 4 branchial clefts evident, stellate chromatophores on head.[159]

Development at unspecified temperature (Sars series): [69]

"A few hours."	First division.

8 days.	Medullary plate formed.	−1.2 C	50 days.[40,43]
10 days.	Optic vesicles formed.	−1.0 C	42 days.[18]
"About 10th day."	First somites formed.		Ca. 50 days.[269]
			60 days.[197]
14 days.	Heart, auditory vesicles, some som-	−0.6 C	

Mean 3.3 C	20 days.[241]
Mean 5.0 C	16 days.[241]
Mean 7.2 C	13 days.[241]
Mean 8.3 C	10 days.[112]
	11–14 days.[96]

Incubation at various temperature ranges:

0.0 to 9.4 C	216 to 762 hours.[182]
3.0 to 4.0 C	20 to 25 days.[56]
3.3 to 3.9 C	20 to 23 days.[240]
3.0 to 5.0 C	40 days.[55]
5.0 to 6.0 C	Ca. 14 days.[252]
6.0 to 7.0 C	Probably 16 days.[243]
7.0 to 8.0 C	15 days.[55]
7.2 to 8.9 C	11 to 12 days.[116]
10.0 to 11.0 C	11 days.[55]

TABLE 8. Incubation at various combinations of temperature and salinity [127]

Temperature C	Salinity ppm	Time to 50% hatch (days)	Duration of hatching period (days)
2	30	21	16
2	32	22	6
2	34	21	8
2	36	24	11
4	26	18	5
4	28	18	5
4	30	17	6
4	32	13	8
4	34	13	6
4	36	13	5
6	26	12	3
6	28	12	3
6	30	12	3
6	32	12	5
6	34	12	3
6	36	12	3
8	26	10	5
8	28	10	3
8	30	11	3
8	32	10	2
8	34	11	5
8	36	10	4
10	26	9	3
10	28	9	3
10	30	9	2
10	32	9	2
10	34	9	2
10	36	9	3
12	26	8	1
12	28	8	3
12	30	8	3
12	32	9	2
12	34	9	3
12	36	8	3

Notes on incubation: Bonnet reared eggs which went from 2-cell stage to 50% hatch at 12 C in 8.5 days, at 10 C in 9 days, at 8 C in 11.5 days, and at 6 C in 17.2 days.[124] Eggs reared at minus 1.0 C for 35 days hatched in an average completion time of 2.5 days when transferred to 6.0 C.[48]

Johansen and Krogh found an upper incubation temperature of 10.2 C [124] although others have observed hatching at 14.0–15.0 C.[18,43,135,159,186] Eggs at "high temperatures" hatch prematurely and the larvae die; [241] hatchlings from eggs reared at ca. 7.5 C are "frail and weak"; [256] and there is an increase in mortality at 8.0 to 10.0 C.[135]

Johansen and Krogh noted that development stopped just after appearance of pigment in eggs reared at minus 0.8 to minus 0.2 C (mean minus 0.3 C). Incubation was apparently less successful at temperature gradients of minus 2.1 to minus 1.2 C (mean minus 1.6 C) and minus 1.7 to minus 0.8 C (mean minus 1.2 C).[48] A. Dannevig noted partial development (up to 9 days) at minus 1.4 C, and obtained complete development at 0.0 C,[135] while Bigelow and Schroeder reported 50 to 75% mortality in eggs reared at 0.0 C.[240] The same percent mortality was observed by Howell in all eggs reared below 3.3 C.[196] Price reported that hatching occurred at 2.8 C, but was less successful at lower temperatures.[96] Rognerud noted that larvae hatched below ca. 2.5 C were "frail and weak." [256] Hatching is not syncronous, and the hatching period may vary from 1 to 16 days.[48,127,241] Optimum incubation temperatures have been estimated at 3.0 to 5.0 C,[135] 5.0 to 8.5 C,[96,240] and 2.0 to 8.0 C.[218] The threshold of incubation has been variously estimated as minus 2.0 C [135] and minus 3.6 C.[152]

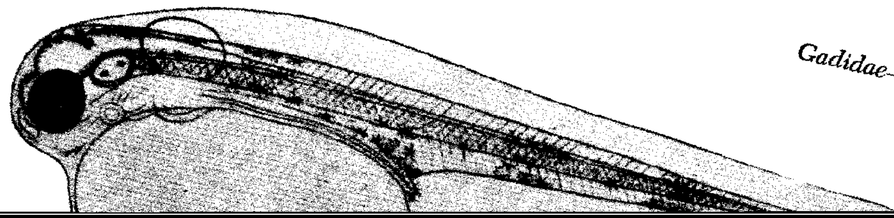
YOLK-SAC LARVAE

Hatching length 3.0 mm [206] or smaller (based on stated average of 3.0 mm) [201] to ca. 5.0 mm.[131] (Cod larvae hatched on shipboard ranged from 3.30 to 5.71 mm in length with averages varying from 3.58 to 4.95 mm, but age at time of measurements was not stated.[141,143]) Length at end of stage 4.0 [159] (although apparently more often 4.5 [21,32,102,136,158,206,214]) to 5.19 mm.[109] Duration of stage 7 [44,159] to 15 days [32,241] and varying with temperature. Twelve days at 7.2 C.[219] Feeding may begin in specimens as small as 3.0 to 3.2 mm which still retain yolk.[208,268]

Abdominal vertebrae, 18–20.[275]

In a specimen 4.71 mm, preanal distance 1.83 mm.[132]

Body thin,[69] curved; [96,241] head rounded, deflected downward at hatching; [69] snout free of yolk in 3 days.[159] Mouth not open at hatching,[117] open in 3 to 7 days; [44,159] mandible extended beyond upper jaw by 4th day.[159] Brain with distinct mesencephalic flexure at hatching.[29] Choroid fissure still evident at 5.0 mm or on 3rd day.[26,124] Otoliths closer to eyes by 3rd day than in earlier stages.[162] Gills without filaments at hatching,[29] gill clefts distinct at ca. 4.0 mm or at 1 day.[44] Notochord multicolumnar.[244] Forward part of dorsal finfold developed as supracephalic sinus; supracephalic sinus small at hatching, elevated at 1 day, well-developed at 4th



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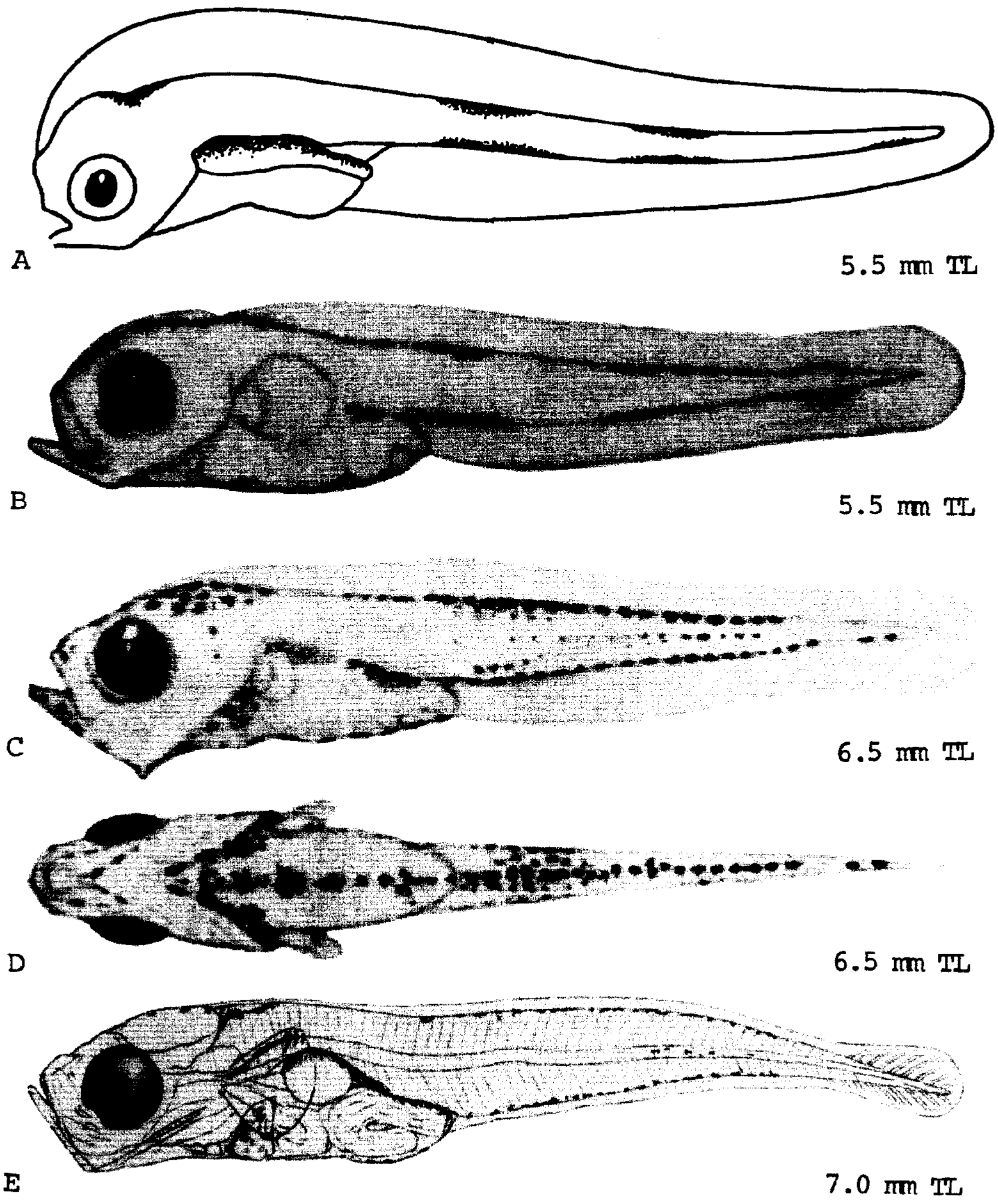


Fig. 150. *Gadus morhua*, Atlantic cod. A. Larva, 5.5 mm. B. Larva, 5.5 mm. C. Larva, 6.5 mm. D. Ventral view of C. E. Larva, 7.0 mm, incipient rays in caudal fin, gut coiling evident. (A, *Colton, J. B., Jr., and R. R. Marak, 1969: 24. B-D, Schmidt, J., 1905: pl. I. E, Masterman, A. T., 1901: pl. I.*)

Dorsal pigment bands shorter than corresponding ventral bands (opposite in pollock).[34,77] Pigment bands vary geographically. In North Sea, sometimes lack postanal bands[214] (as well as mediolateral streak which develops later in stage in some populations).[158] In Murmansk, posteriormost band often lacking, preanal ventral pigment very light.[10] Melanophores in dorsal wall of peritoneum, especially over swim bladder and, sometimes, scattered chromatophores over brain.[136] Eye deep black;[158] also described, without reference to length or age of specimens, as having a bright bronze-like hue.[159]

At 4.0 mm typical pattern with additional chromatophores on head, at angle of mandible, and on ventral surface of abdomen. Eyes deeply pigmented and with bluish silvery sheen.[159]

At 4.5 mm pigment bars sometimes partly or completely fused, a mid-ventral line of pigment from anus to near tip of tail, an oblique streak of abdominal pigment, and few large stellate chromatophores in occiput. Body with diffuse yellow-green tinge, especially over head.[136,158]

At 3.30 to 5.19 mm scattered chromatophores on back of head, pigment over gut increased.[109]

At ca. 5.0 to 5.2 mm dorsal elements of postanal bars approaching one another; [136] chromatophores present [159] or absent on head and jaws,[277] row of chromatophores forming along lateral line; internal pigment increased to include liver and pericardium; [136] subnotochordal black band; [159] eye with purplish sheen, stomach sometimes stained pinkish by ingested copopods.[277] Greenish yellow coloration on head, snout, and dorsal region of body.[159]

LARVAE

Minimum size ca. 4.5 [275]–5.5 mm; [44] size at end of stage 24 [206] (or possibly as small as 20 mm) [13]–30 mm.[214]

Abdominal vertebrae, 17–20, average 18.4.[33]

At 9.5 mm nasal region elongated, mandible horizontal,[277] lower jaw projecting.[69] Choroid fissure evident to at least 6.0 mm.[159] Teeth apparent at 19.0 mm.[136] Brachiae of gills with simple papillae at 8.0 mm.[159] Development of barbel variable, reported first evident over a size range of 7.0 to 19.0 mm,[136,268] but also noted as absent in specimens up to 30.0 mm long.[13,214] Urostyle oblique at 9.5 mm [277] to 11.0 mm.[152,158,211] Lateral line sharply defined at 11.0 mm.[136] At 8.0–9.0 mm anlagen of D. 2, D. 3, A. 1, and A. 2 present as thickenings in finfold; [158,159] fin ray development in unpaired fins first evident at 9.0 mm [190,214] (a report of many embryonic rays at 7.0 mm [159] is questioned, JDH). Incipient rays in D. 1 at 12.0–13.0 mm and in D. 2 and D. 3 at 11.0 mm; [158,206,214] D. 2 and D. 3 complete at 20.0 mm; [158] D. 1 complete at ca. 26–30 mm.[214] Incipient anal rays over size range of 10.0–13.0 mm; [71,158,206] anal fins complete at 20.0 mm; [240] at ca. 15.0–30.0 mm, A. 1 not extended backward further than D. 2.[158,211] Remnants of finfold evident at 20.0 and 24.0 mm.[13,136,214] Incipient caudal rays at 6.5 [158] to 9.0 mm; [206] at 20.0 mm accessory fin rays above and below tail which exceed definitive number of caudal rays; [67] caudal fin initially rounded,[25] symmetrical at ca. 8.5 mm,[277] immarginate at 9.0 mm,[136] squared posteriorly and with an essentially straight edge at ca. 15.0–30.0 mm.[158,211,214] Pelvic buds barely evident at 8.0 [159]–8.5 mm, developed as knob-like processes at 13.0 mm; pelvic fins half diameter of eye at 16.0 mm,[158] with elongate rays at ca. 23.0 mm,[159] and "moved forward" at 24.0 mm.[136] At 7.0 mm intestine beginning to fold,[256] at 7.0–19.0 mm stomach and pyloric caeca formed.[268] Anus under D. 2 through size range of ca. 15.0–30.0 mm.[158,211,214] *Ductus pneumaticus* obliterated at 6.5 mm; [47] gas bladder oval at 9.0 mm,[136] somewhat elongate at 13.0 mm.[159]

Pigmentation: Pigment pattern of yolk-sac larvae retained to ca. 7.0 [33] or 8.0 mm; [211,240] at ca. 4.5 mm dorsal pigment bars distinctly doubled, 1–3 melanophores on ventral side of tail tip.[275] At ca. 9.0–11.0 mm original pigment groupings barely evident, usually a single chromatophore on underside of tail.[214] By 10.0 mm pigment bars fused (so that postanal pigment is indistinguishable from that of pollock and haddock),[33] a median pigment band formed, and dorsal pigment less pronounced than ventral pigment. At 10.0–20.0 mm pigment extended on to tail [158,211,240] and general pattern more diffuse.[109] Larvae translucent green and white, with bluish black eyes, and both black and yellow pigment on head and body.[83,113,194] Pigmentation varies geographically, specimens from southern North Sea and west of Scotland may be only faintly pigmented.[211] Pigment also affected by environment, paling at low temperatures and salinity.[113]

At 5.7 mm 2 postanal bands fused; a trace of lateral chromatophores in caudal region; chromatophores on head and on venter from jaw to anus, chiefly in midline. General color uniform greenish yellow.[277]

At 6.0 mm pigment generally as above, but mid-ventral pigment developed beyond anus, and a pair of short postanal pigment rows along lateral line.[136]

At 6.5 mm ventral postanal streak extended further back on tail, mediolateral streak developing along posterior part of body, few chromatophores in dorsolateral region, yellow pigment on dorsal and ventral aspects of body.[158,214]

At 7.0 mm pigment intensified, postanal pigment bands well-fused and forming a single dorsal and ventral streak, mediolateral streak more developed, a characteristic pigment blotch evident over pectorals, internal pigment increased, general ground color more yellowish.[136,159,256]

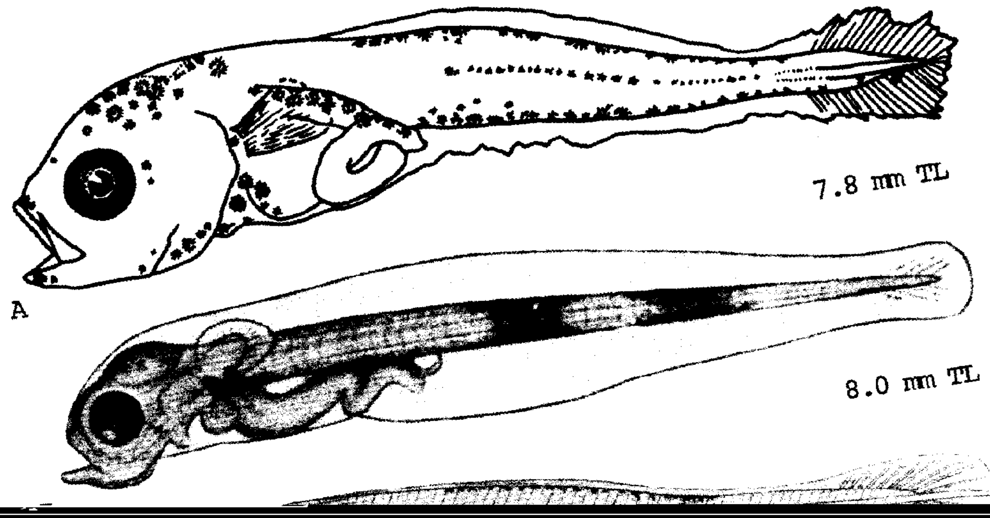
At 8.0 mm black pigment on top of head, along base of dorsal and ventral finfolds (although less distinct ventrally). A mostly internal line of pigment from pectoral base to anus, few melanophores between developing caudal rays. Eyes bluish silvery. Body yellowish green with greenish translucency.[159]

At ca. 8.5 mm pigment more pronounced, scattered yellow chromatophores over head and back.[277]

At 9.0 mm postanal pigment bars essentially obliterated; mediolateral, dorsolateral, and ventrolateral pigment now strong; a line of pigment over dorsal aspect of neural tube; yellow pigment increased; body with greenish translucency.[136,158]

At 9.5 mm pigment more abundant and distributed mainly in dorsal and lateral bands and in large patches on head and stomach.[277]

At 11.0 mm first ventral pigment bar reduced to a single chromatophore, a conspicuous mass of black pigment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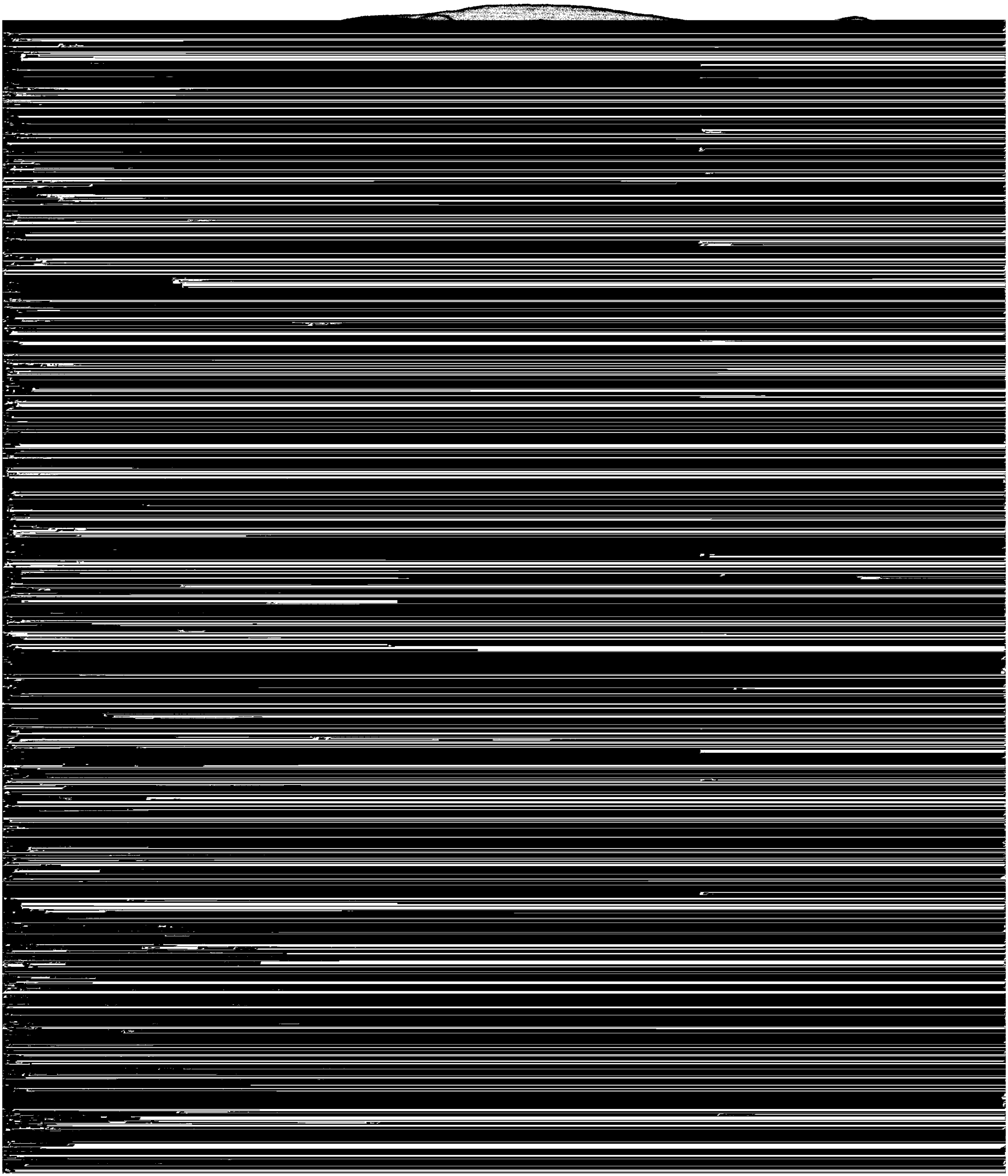
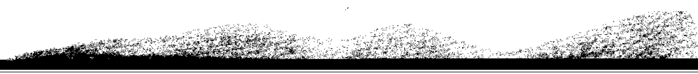




over brain, patches of pigment on jaws and snout.[136,158]

At 12.0–13.0 mm yellow pigment increased on flanks, silvery sheen evident in abdominal region.[214]

At 16.0 mm mediolateral streak extended posteriorly toward end of tail, yellow pigment extended to middle of sides, forward part of abdominal region with slight silvery sheen.[158]

At 20.0 mm yellow pigment diffusely scattered over entire side, dorsal surface uniformly covered with pigment.[13,158]

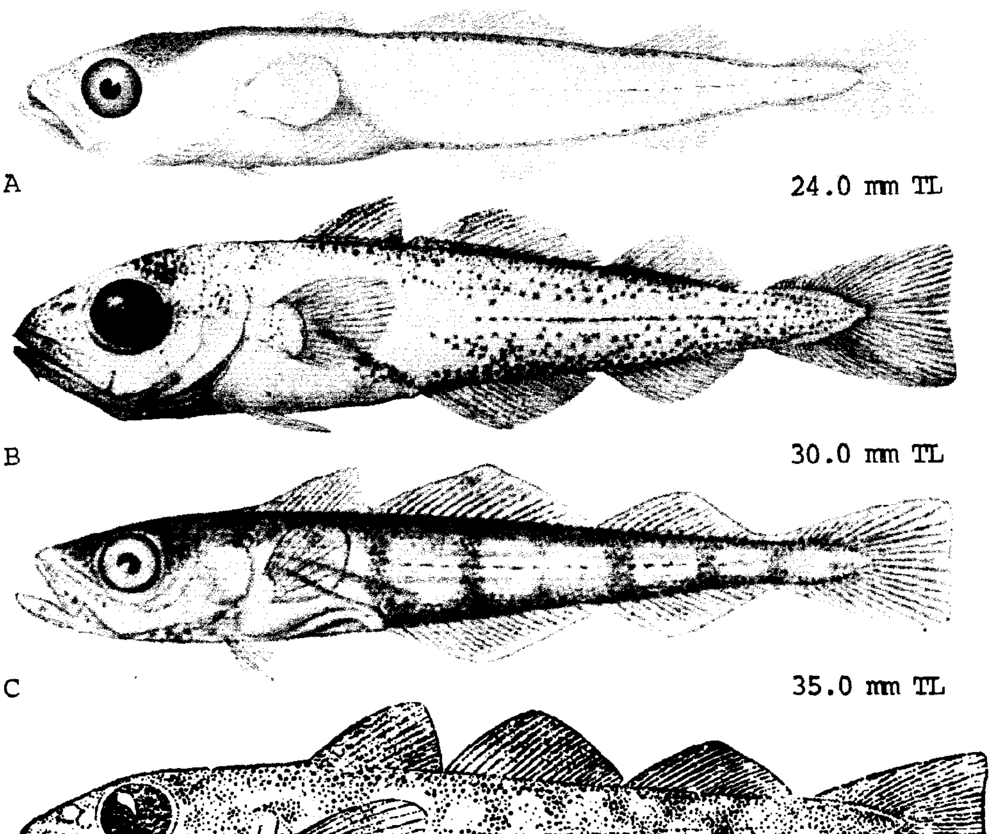
At ca. 23.0 mm stellate chromatophores thinly scattered on sides.[159]

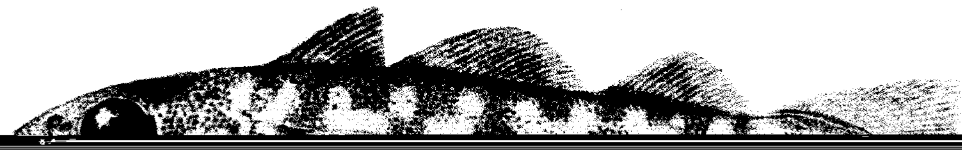
At 24.0 mm mid-ventral line of pigment from throat to anus no longer visible.[136]

At 30.0 mm mediolateral streak very distinct, occipital pigment more dense, yellow pigment extended to caudal fin, belly silvery[158] (note lack of checkered prejuvenile pattern at this size, JDH).

PREJUVENILES

Minimum length 24 mm[206] (or possibly smaller).[13,268] Length at end of stage ca. 45.0[32] or possibly 95.0 mm[163,240] and with both length at time of development of checkered pattern[214] and descent to bottom varying





white, traces of dark bands still evident, and body with golden tinge.[241]

JUVENILES

Minimum length 45 [32] to ca. 50 mm.[159]

Abdominal vertebrae, 17–20.[109]

At 12 to 18 months adult-like in general appearance.[241] Scales first evident (in some specimens) beneath each melanophore above and below lateral line at 40–50 mm.[206] Minimum sclerites at 50–80 mm, large sclerites at ca. 110–120 mm.[148] Pelvics nearly as long as pectorals in young, proportionately shorter with age.[240] Sexes not distinguishable for first 2 years; ovaries evident after 2 years as very thin tubes along dorsal and caudal part of body cavity.[23]

Pigmentation: Juveniles from ca. 100 to ca. 380 mm or weighing up to a few pounds sometimes reddish;[17,30,241] "small cod" also described as "dark."[35] Pigmentation apparently varies with habitat: thus at 1 year (ca. 305 mm) reddish yellow when living among algae, light green or grayish over sand;[159] one year old fish also described as very light grayish green with silvery gloss on sides, and usually, dark spots.[255]

AGE AND SIZE AT MATURITY

2 [35,57,196] to 16 years [228] with males usually maturing before females [235,242] and sometimes with a difference of as much as one year (thus, in some populations, males in 3rd year, females in 4th [17,228]). Averages have been estimated from 2.2 to 2.7 years [249] and from 7.8 to 9.9 years.[204]

In Labrador, 6 to 11 years, with males usually in 7th year and females usually in 8th year.[86,88,89] In Newfoundland 3 to 10 years,[89,145] but with only 2% of population at 4 years;[24] usually in 7th or 8th years with females "a little later than males."[89] In Belle Island 6 to 10 years, but usually 7th or 8th year.[86] In Gulf of

gonads at age of 2 years.[176,210] In Skagerrak, Kattegat, Belt Sea, and Baltic ca. 24% of age group II mature in northern area and over 75% of age group II mature in southern area.[157] In Skagerrak 54% of age group III spawning, 95% of age group 5.[175] In Faroes some as early as 2 years,[130] mostly at 5 years.[242] In Iceland some cod mature during 3rd year,[237] but such fish probably do not spawn until 4th year.[62,70,110,185,212,228] Saemundsson gives the following minimums for Iceland: males 3 (rarely) to 5 years on south and west coast, 5 to 6 years on north and east coast; females 4 (rarely) to 6 years on south and west coast, 5 to 9 years on north and east coast.[220] Maximum age at first maturity, 16 years.[228] Majority usually mature between 7th [178] and 10th year,[260] with overall average estimated at 7.8 years.[62] One author presents somewhat lower estimates: males at 4 to 7 years, females at 5 to 9 years.[70] Cod mature earlier in warmer waters of southern coast than in cooler waters of northern coast,[110,228] and average age at first maturity may shift from year to year in a single population.[94,180] In Greenland 5th to 11th year [89,95,131] (although few in 5th year); [110] usually in 7th to 9th year.[86,88] Hansen [204] has demonstrated a decrease in minimum size and age at maturity in Greenland cod (Table 9).

TABLE 9. Minimum size and age at maturity of Greenland cod in different years (Hansen, 1949)

	Year class	Age at maturity	Average age at maturity
Northern Greenland			
	1917	6–15	9.9
	1922	6–13	8.6
	1924		6.4
	1934	7–9	7.8
	1936	7–9	6.9
Southern Greenland			
	1922		9.3
	1932		8.1
	1934		7.8
	1936		7.6

Hjort, speaking of cod generally, pointed out that average age at maturity may decrease as fishing pressure increases.[166]

Minimum length at maturity possibly between 156–200 mm; but this is well below other minimum estimates female 540 mm; largest immature male 890 mm, largest immature female 970 mm; average for females ca. 740 [redacted]

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171. Fish, C. J., 1930:259, 268, 270, 291–2.
172. Saemundsson, B., 1913:30.
173. Schmidt, J., 1907:21.
174. Hansen, P. M., 1934:9.
175. Dannevig, A., 1954:1.
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177. Jean, Y., 1954:120–4.
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Melanogrammus aeglefinus (Linnaeus), Haddock

ADULTS

D. $_1$ 13–18 [80] (w. Atlantic 14–17),[17,114] D. $_2$ 19–25 [14,80] (w. Atlantic 20–24),[17,114] D. $_3$ 18 [51]–23 [80] (w. Atlantic 19–22).[17,114] A. $_1$ 21 [17]–28 [51] (w. Atlantic 21–25),[114] A. $_2$ 19 [51]–24 [17] (w. Atlantic 20–24).[114] P. 19–21.[125] Scales in lateral line, ca. 160; [17] gill rakers, 24–27; [14] preanal vertebrae 19–22, postanal vertebrae 32–35 (based on Icelandic population),[80,94] total vertebrae 50–57 (excluding hypurals),[42] average vertebrae counts vary from 53.58 to 54.12 in the western Atlantic.[120]

Proportions expressed as percent body length: Predorsal distance 26.1–28.2; preanal distance 41.7–45.5; base of D. $_1$, 12.2–13.8; base of D. $_2$, 19.7–23.5; base of D. $_3$, 13.6–16.4; base of A. $_1$, 21.1–22.8; base of A. $_2$, 13.8–16.5. Eye diameter as percent HL, 20.0–28.2.[14]

Body laterally compressed; upper jaw projecting, lower jaw with single barbel, its length less than diameter of eye; gape not extending below eye. First dorsal fin pointed, higher than 2nd dorsal, and with its margin slightly concave; pelvics in front of pectorals; caudal fin lunate.[17,114,125]

Pigmentation: Top of head and dorsal surfaces down to lateral line dark purplish gray or dark gray with violet shadings; lateral line black; sides below lateral line silvery gray with pinkish reflections; belly and lower parts of head milky white. A large, conspicuous dark blotch on each shoulder between lateral line and middle section of pectoral fin. Dorsal, pectoral, and caudal fins dark gray; anal fin pale and with black specks at base; pelvics white, more or less dotted with darker color. Peritoneum black. Occasional specimens with 1–4 transverse bars or splotches in addition to shoulder patch. Rare individuals golden on back and sides and with lateral line golden.[9,14,80,114,125]

Maximum length: Ca. 1118 mm.[107]

DISTRIBUTION AND ECOLOGY

Range: In western Atlantic, Gulf of St. Lawrence and Newfoundland Banks to Cape Hatteras, North Carolina. In Europe from vicinity of Matochkin Shar in Novaya Zemlya to the Bay of Biscay, France, and including the Orkney, Faroe, and Shetland Islands, England, Ireland, and Scotland, the western Baltic, Bear Island, Spitsbergen, the western coast of the White Sea, and, possibly, the Kara Sea. Also Iceland and the southern tip of Greenland.[6,14,19,35,50,114,125]

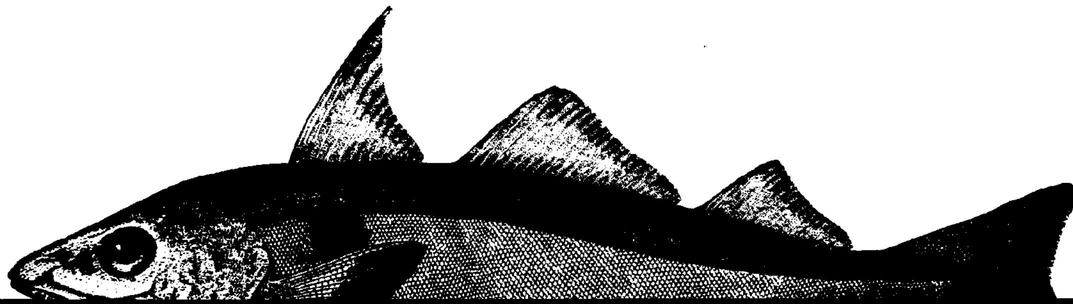
Area distribution: Worcester County, Maryland; [55] offshore waters of Virginia; [32] and offshore waters of New Jersey [30,99] and Delaware Bay.[60]

Habitat and movements: Adults—a bottom species [1,6,27] found in marine waters and, sometimes, fjords [91] over bottoms of sand, rock, pebbles, gravel, or broken shell. Sometimes associated with banks and ledges and sometimes over smooth areas between rocky patches; [6,9,47,57,107,108] also reported from "slimy" bottoms.[99] Deep water channels apparently act as barriers to movement.[17] Sometimes form large compact schools.[9,31,35] Usual depths variously estimated, but ranging from 20–275 m,[9,27,47,63,92,108,110] although at least one author regards it as rare below 185 m.[98] Maximum reported depth, 1000 m,[14] but other reported maximums from 323–402 m.[9,126,128] Reported from less than 25 ppt to over 34.5 ppt [1,105] (Damas gives an optimum salinity of 35.0 to 35.2 ppt [49]). Reported from range of 0 [98] to 13 C,[105] but known to survive experimentally at 20 C; [97] optimum 4 to 7 C,[14,25,97] most abundant at ca. 2 to 9 C,[17] feeding range 2.2 to 11.9 C.[112] There are apparently seasonal shifts in preferred temperature. In Canadian waters winter temperatures vary from 3 to 6 C, summer temperatures from 6 to 8 C.[139]

Haddock undertake only relatively short inshore-offshore or coastwise movements and there are no extensive long distance mass migrations.[9] In the western Atlantic there are apparently three distinct stocks of haddock (New England, Nova Scotia, and Newfoundland), all with limited migrations.[23] The more extensive migrations occur in Canadian waters, while those in New England are noticeably less. Generally, haddock spend the winter in deeper water, and move shoreward in summer, spreading into warmer, shallow, coastal water.[17] In Nova Scotia there is an apparent spawning migration to offshore banks during early spring,[4] with spent fish returning inshore in May and June,[41] however, those on Georges Bank do not migrate.[113] Inshore and offshore migrations have also been documented for St. Pierre Bank and Southern Grand Bank with the movement to shallow water beginning in April in the latter locality.[130,135,139] A southern migration from Passamaquoddy Bay takes place in March and April.[3] Individuals from New England move southward to New York, New Jersey, and, rarely, Cape Hatteras in winter (and it is this migration which accounts for the regional records).[107] Colton concludes that haddock on Georges Bank seek shoaler water during the spawning season than during the summer months.[113] In the North Sea a northward spawning migration occurs in January and April,[21] and there is a general tendency for older individuals to migrate into deeper water.[83] In Iceland there is a migration from Faxa Bay to Selvogsbanki from April to May.[109] Icelandic haddock apparently move into deeper water to spawn.[27]

Diurnal movements may occur with the species rising to midwater at night,[134] although, in some areas at least, this pattern may be reversed during the spring months.[101]

Larvae—typically oceanic,[46] although also recorded from



possibly 75 m, with over 80% at 10 to 40 m, the maximum concentration at 20 to 30 m, and the maximum density at 20 m.[34,90] Over 80% of specimens 8 to 21 mm long are concentrated in the thermocline, while specimens 4 to 8 mm long tend to be below the thermocline.[34,90,129] In the North Sea larvae are concentrated at 20 to 50 m.[92] Minimum reported salinity 15 to 18 ppt.[59]

Drift with surface currents.[14,125] In some areas wind direction and intensity can affect survival of larvae,[141] as, for example, on Georges Bank where survival is lowered when larvae are carried into slope water.[90] Some vertical movement occurs but varies from area to area.[34]

Juveniles—on Georges Bank small juveniles tend to concentrate in water column in depths shoaler than 20 m[90] and specimens 40 to 77 mm long have been collected in Narragansett Bay.[28] Juveniles of various sizes (see movements and depth) reported from deep offshore waters,[94] coastal areas, bays, inlets, and fjords.[53,104,125] Holt reports numerous young ca. 125 mm long cast ashore during a storm in England.[38] In Nova Scotia specimens 200 to 400 mm long are found on bottom along shore during summer months.[97] A specimen ca. 160 mm long and individuals in year class I have been reported over muddy bottoms at depths of, respectively, 51 and 134 m.[21,78] Specimens ca. 20 to 100 mm long may be in the water column and associated with jellyfish, and up to several dozen fry may hide under a single *Cyanea*. On Georges Bank juveniles larger than 20 mm were never found in areas where *Cyanea* was not present.[6,40,48,90,125] Variously reported from 5[82] to 177 m[74] although specimens 30 to 60 mm long may be found *over* depths of 4000 to 5000 m,[94] and recently descended juveniles may survive at depths of up to ca. 293 m.[58] Specimens ca. 60 to 90 mm long have been recorded from ca. 19 to 177 m, and Holt has suggested a nursery area between ca. 40 and 98 m in European waters.[74] Members of year class I have been taken at 134 m,[21] year class II at 5 to 30 m,[82] and specimens ca. 250–425 mm long at ca. 7–8 m.[111] In the northwestern Atlantic over 75% of all "juveniles" up to 124 mm were found at 10–40 m, with none below 80 m in studies of the upper 100 m.[201] In one study specimens 24 to 80 mm, 40 to 48 km offshore.[20] North Sea specimens recorded from 32.1 to 35.1 ppt.[21] Recorded from 6.5 to 15.7 C, but tend to avoid temperatures above ca. 10 to 11 C. Survive experimentally at 20 C.[21,68,111]

110–120 mm long may occur pelagically, but this may represent a return to the surface after descending.[21,92] Descent usually occurs in water 10 to 120 m deep (based on Icelandic observations),[71] although seldom in water less than ca. 20 m deep.[107] Apparently can sound to depths of ca. 293 m, but cannot survive following soundings in greater depths.[58]

Small juveniles initially remain in the open sea and are more or less stationary.[87,98,103] Specimens up to and during their 2nd year of life may ascend to surface, particularly during autumn.[66] In North Sea and other areas a general shoreward movement takes place, primarily at the beginning of the 2nd year[14,33,89,104] with "small juveniles" concentrating at depths of 20 m or less in some areas,[90] but this does not hold true for Georges Bank specimens (RRM). Specimens ca. 190–225 mm long are reported to move inshore in "immense shoals."[29] Young which have moved inshore return (with rare exceptions) to deeper water in winter.[14,89,137] In the Barents Sea individuals from the beginning of their 3rd year to the time of maturity undertake seasonal migrations, moving from east to west as the water cools in autumn.[14]

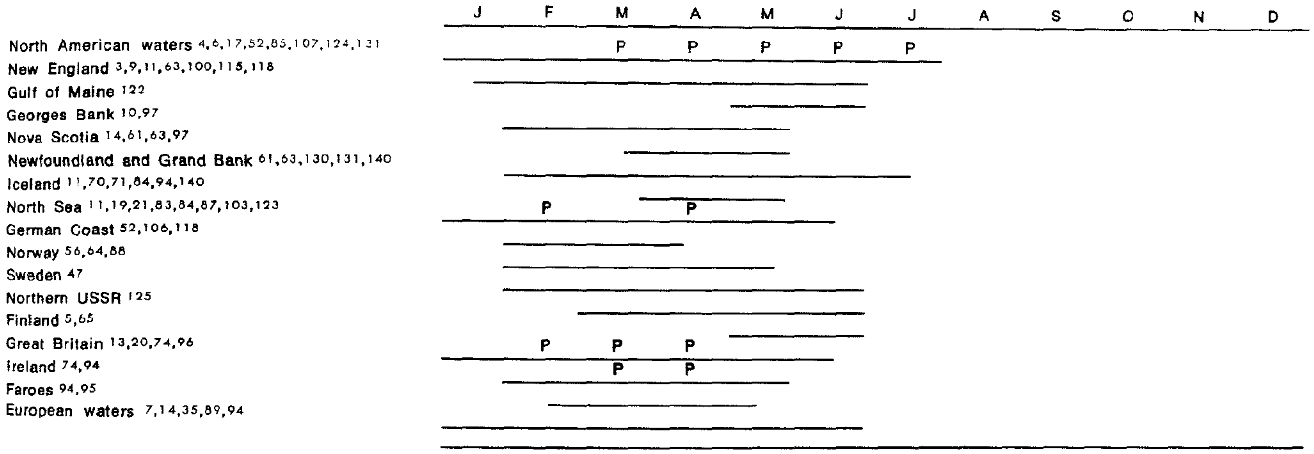
In the northwestern Atlantic, diurnal variations have been reported. Juveniles were found at an average depth of 40 m by day and 30 m at night.[129]

SPAWNING

Location: At or near bottom[9,34,63,75] over rocks,[52,118] gravel, smooth sand,[107] or soft mud.[89] Usually 8 to 32 km from shore, although sometimes up to 96 km out,[26] and typically over offshore banks and slopes.[9,17,46,61,111,141] Inshore spawning has been reported,[24] but is apparently of little importance.[17] In European waters spawning probably occurs northward to at least 65° N latitude, and has been observed southward to the English Channel and the waters south of Ireland.[19,79,106] In the Faroes there are distinct loci of spawning density near edges of shelves, and these loci do not vary significantly from year to year;[8,79] Georges Bank populations also quite consistent about sites (RRM).

Depth: In American waters ca. 30 to 211 m, but mostly at less than ca. 48 m.[113] In European waters from 20[33] [illegible]

TABLE 10. Spawning season of *Melanogrammus aeglefinus*. P indicates peak spawning period.



than in more shallow areas,[87,92] and the season varies considerably from year to year[85] and with latitude.[125]

Temperature: In North America 2.5 to 6.5 C,[14,90] with maximum activity (in the Georges Bank area) at 3.3 to 5.6 C.[143] A 1.5 to 2.0 C temperature change can mean a difference of one month in the spawning season.[132] In European waters 4 to 10 C, with optimum temperatures varying from 4 to 8 C in some areas to as high as 10 C in others.[5,7,10,14,49,88,125] In Iceland, minimum favorable temperature 5.5 C.[102]

Salinity: In American waters 32.0 to 32.5 ppt.[14] (In the Grand Bank area most successful year classes are correlated with low numbers of icebergs passing south of 48° N in eastern Newfoundland,[140] an effect which may result from salinity changes.) In European waters generally somewhat higher than in American waters (34.00 to 35.25 ppt)[7,49,59,92] although reported at ca. 32.0 to 33.0 ppt in the Barents Sea.[5]

Frequency: Eggs are released at intervals over a period of about three weeks.[143]

Fecundity: Extreme counts, 12,000 to 3,000,000. Estimated averages vary from ca. 31,000 in 2 year olds to as high as 2,158,000 in older fish. Although fecundity increases with age and size, it may vary significantly in same-size fish from year to year and this may be correlated with temperature.[61,125,136] There are apparently differences in fecundity between populations on opposite sides of the Atlantic.[131] Two types of eggs (opaque-yolked and transparent yolkless) appear in the ovaries simultaneously.[136]

EGGS

Location: Initially at bottom, but become buoyant a few minutes after fertilization[34] (which may be delayed up to 16 hours[9,73]); in Georges Bank area rise at rate of ca. 3 m per hour, thus from 70 m depth to surface in ca. 24 hours.[75] After arriving at surface buoyant,[17] pelagic,[6,29,44] but density varies with stage of development[75] and eggs may descend to mid- or bottom depths as development proceeds.[92] Normally concentrated in upper 10 m,[58] relatively abundant down to ca. 50 m, maximum depth 115–170 m.[129] In eastern Atlantic normally found between latitudes 58–50° N[96] over depths of 17 to 360 m, but mostly over 50 to 200 m and at temperatures of 5 to 10 C and salinities greater than 34.5 ppt.[71,94] Eggs may drift at surface for a week or more[17] and at times, as in area of Georges Bank, may be carried into deep water where only a few survive.[90]

Ovarian eggs: At less than 0.1 mm gray, yolkless; at 0.5 to 1.0 mm opaque, yellow; at ca. 1.5 mm translucent.[61]

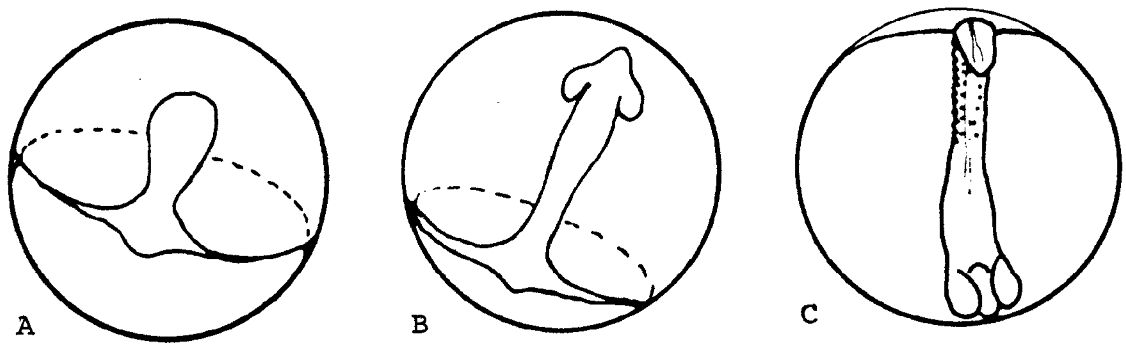
Unfertilized eggs: 1.20[19] to 1.50 mm.[117] Running ripe eggs transparent or light amber.[10] Micropyle shaped like reverse funnel, small opening on outside, large opening on inside; area around micropyle granular.[78]

Fertilized eggs: Diameter 1.10[12,44] to 1.72 mm,[86] averages ca. 1.46 mm[12,26,44] (although average size decreases with advancing season,[11] from 1.54 to 1.45 mm or 6.0 percent in North American waters,[76] 1.526 to 1.342 mm in North Sea[96]), spherical,[29] sometimes ellipsoidal;[45] blastodisc light terra cotta, but only in very early stages;[26,116] zona radiata extremely thin;[73] egg membrane comparatively fragile,[11] soft,[96] thin, and breaking up into flakes as hatching approaches;[73] no oil globules.[13,29,106]

EGG DEVELOPMENT

Development at 5.5 C (Schwarz series):[121]

7th day.	Blastopore closed.
11th day.	Anlagen of swim bladder evident as shallow evagination of dorsal gut wall at level of pectoral fins.
12th day.	Anlagen of swim bladder a hollow inverted "U."


A
B
C

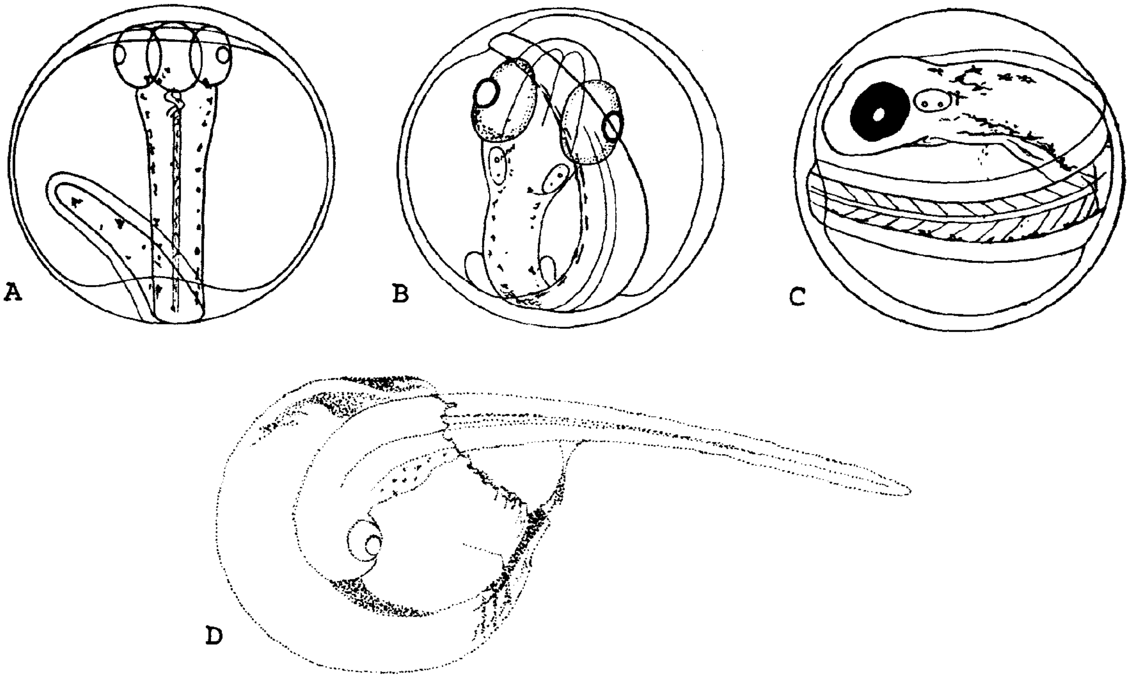


Fig. 158. *Melanogrammus aeglefinus,* Haddock. A-C. Development of egg. A. Early pigment formation, lenses formed. B. Pigment developing in eyes, otoliths evident. C. Body pigment in characteristic pattern, eye fully pigmented. D. Yolk-sac larva hatching. (*A-C, Heincke, F., and E. Ehrenbaum, 1900: fig. 12. D, McIntosh, W. C., and A. T. Masterman, 1897: pl. 3, Tamiko Karr, delineator.*)

13th day.	The "U" elongated.
14th day.	Swim bladder more dorsal in position; first evidence of distinction between pneumatic duct and swim bladder.
15th day.	Swim bladder expanded.
16th day.	Swim bladder more expanded.
17th day.	Hatching. Swim bladder lengthened anterior-posteriorly, pneumatic duct enters approximately at midpoint.[121]

velopment at unspecified temperature (McIntosh and ince series):[73]

2nd day.	Blastodisc 0.4 mm in diameter.
4th day.	Blastoderm to equator, embryonic keel indented into yolk, head defined.
5th day.	Optic lobes distinct, indications of 4–5 somites in anterior caudal region, scattered black pigment on sides and dorsum.

cially in dorsolateral region above pectorals.

13th day.	Lumen of mesenteron enlarged.
15th day.	Cephalic region enlarged, body elongate.
16th day.	Eyes pigmented, first branchial cleft distinct.
18th day.	Eyes black.
19th day.	Three branchial clefts visible, buccal chamber evident, urinary vesicles well advanced.
20th day.	Hatching.[73]

Marak and Livingstone[132] have described six major stages of development (based on temperature of 3.3 C):

I.	From fertilization to formation of early blastodermal cap.	0–72 hours
II.	From complete blastodermal cap to development of segmentation	4–7 days

V. From closure of blastopore to early scattered pigment. — 14–17 days

VI. From formation of characteristic pattern to hatching.[132] — 18–21 days

Miscellaneous comments on development (all at unspecified temperatures): At 6 1/2 hours blastodisc uniform, prominent.[73] Complete differentiation of notochord occurs at time of closure of blastopore.[45] In series in which blastopore closed on 6th day, irregular black spots appeared in dorsolateral region on 8th day. Time of initial appearance of pigment apparently variable: sometimes by 5th day;[86] but in series having 14 day incubation period, not until 10th day.[45] At time at which embryo surrounds egg, a double row of chromatophores on ventral side in postanal region.[11,96] Before hatching black pigment appears in peritoneum.[87] Typical yolk-sac larval pigment is developed before hatching.[12]

Incubation period 6 [20,73,89] to 42 days.[7,18]

Incubation period at various temperatures:

At −1 C	42 days [7,18]
At 2.2 C	25 to 32 days [17]
At 2.8 C	15 days [14,89,124]
At 3.0 C	23 days [7,18]
At 3.3 C	18 to 21 days [132]
At 4.0 C	20.5 days [7,18]

decrease in hatching length has been noted from March to May.[76]

In a 3.6 mm hatchling, anus just anterior to midpoint of TL;[13] in a 4.0 mm hatchling, snout-vent length ca. 38 percent of TL.[96]

At hatching body very plump,[67] blunt;[96] head deflected downward over yolk. Mouth initially not evident,[13] open by 5th day,[20,73] lower jaw well-developed by 4.19 mm.[117] By 5th day anterior nares indicated by lenticular mark.[73] Dorsal finfold forward to posterior part of head throughout stage.[44] Incipient caudal rays present[20] or absent[13] at hatching; dorsal and anal fins without incipient rays throughout stage.[44] Pectorals initially small, rounded;[13] large, lobate, and rayed by end of stage. At 4.19 mm notochord multicolumnar, developing gut slightly convoluted;[117] anus not open at hatching;[13] opened laterally at base of finfold by end of stage.[12] At time of hatching gas bladder more anterior than previously, pneumatic duct far posterior; by 3rd day (average TL 3.8 mm) gas bladder still further forward, tapered caudally to meet pneumatic duct; at average length of 4.3 mm *"rete mirabile"* (a collar almost surrounding the gas bladder) evident.[121]

Pigmentation: Generally scattered chromatophores on back of head and over gut; stellate chromatophores over

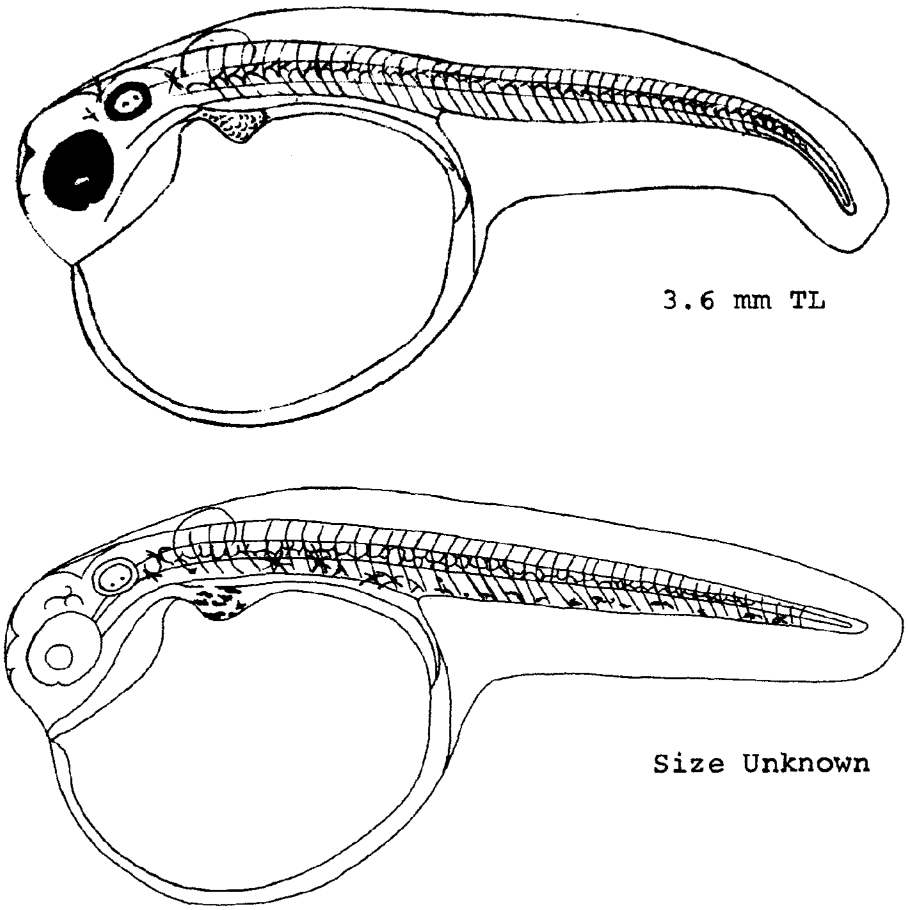


Fig. 159. *Melanogrammus aeglefinus*, Haddock. A. Yolk-sac larva, 3.6 mm TL, ventral pigment not shown. B. Yolk-sac larvae, pigment illustrated, size unknown. (*A, Cunningham, J. T., 1888b: pl. 6. B, Cunningham, J. T., 1896: fig. 131, Tamiko Karr, delineator.*)

patch on top of head directly above eyes, in region more or less above pectoral fins, and over gut.[12]

LARVAE

Size range 4.0 mm (average size at loss of yolk 4.3 mm) [121] to ca. 28 mm.[17]

Abdominal vertebrae 19–22, average 20.3.[12]

At 6.75 to 11.0 mm body thick, plump; head large.[20,72,94] At 6.75 mm finfold quite broad; dorsal finfold extended forward to front of eye.[72] At sizes up to 19.0 mm finfold continuous; [96] at 25.0 mm unpaired fins entirely separated.[72] Incipient rays first evident in caudal at 4.2 mm, in other unpaired fins at ca. 9.0 to 10.0 mm.[72,87,96] At 11.0 mm not all rays in dorsal, anal, and caudal formed; first dorsal last unpaired fin to develop.[20] At 25.0 mm corners of caudal fin rounded, posterior border almost straight; [72] at ca. 25.0 mm 1st dorsal acutely pointed.[170] Pectorals with incipient rays at 6.75 mm; [72] at ca. 16.0 mm to 19.0 mm pectorals extended to anterior border of D_2.[96] Pelvics first evident at 6.75 mm [72] to ca. 8.0 mm; [22] rays evident at ca. 11.0 mm. At 9.0 mm pelvics wart-like; at 10.0 mm length equal to ca. 1/2 diameter of eye; at 13.5 mm ca. 3/4 diameter of eye; at 19.0 mm longer than diameter of eye and more than half way to anus; [72] at 26.0 mm to anus.[76] Notochord oblique and extended into caudal fin at ca. 8.0 to 11.25 mm.[22,72,96] At sizes of ca. 8.0 to 20.0 mm, anus under 2nd dorsal fin.[67] At 10 days (average length ca. 4.8 mm) lining of cavity of gas bladder somewhat folded; at 12 days (average length still 4.8 mm) lining more convoluted, pneumatic duct greatly constricted or entirely closed; minimum length at closure of pneumatic duct in field caught specimens 4.5 mm; former position of pneumatic duct evident as thickening in outer wall of gut in specimens up to 17.5 mm long.

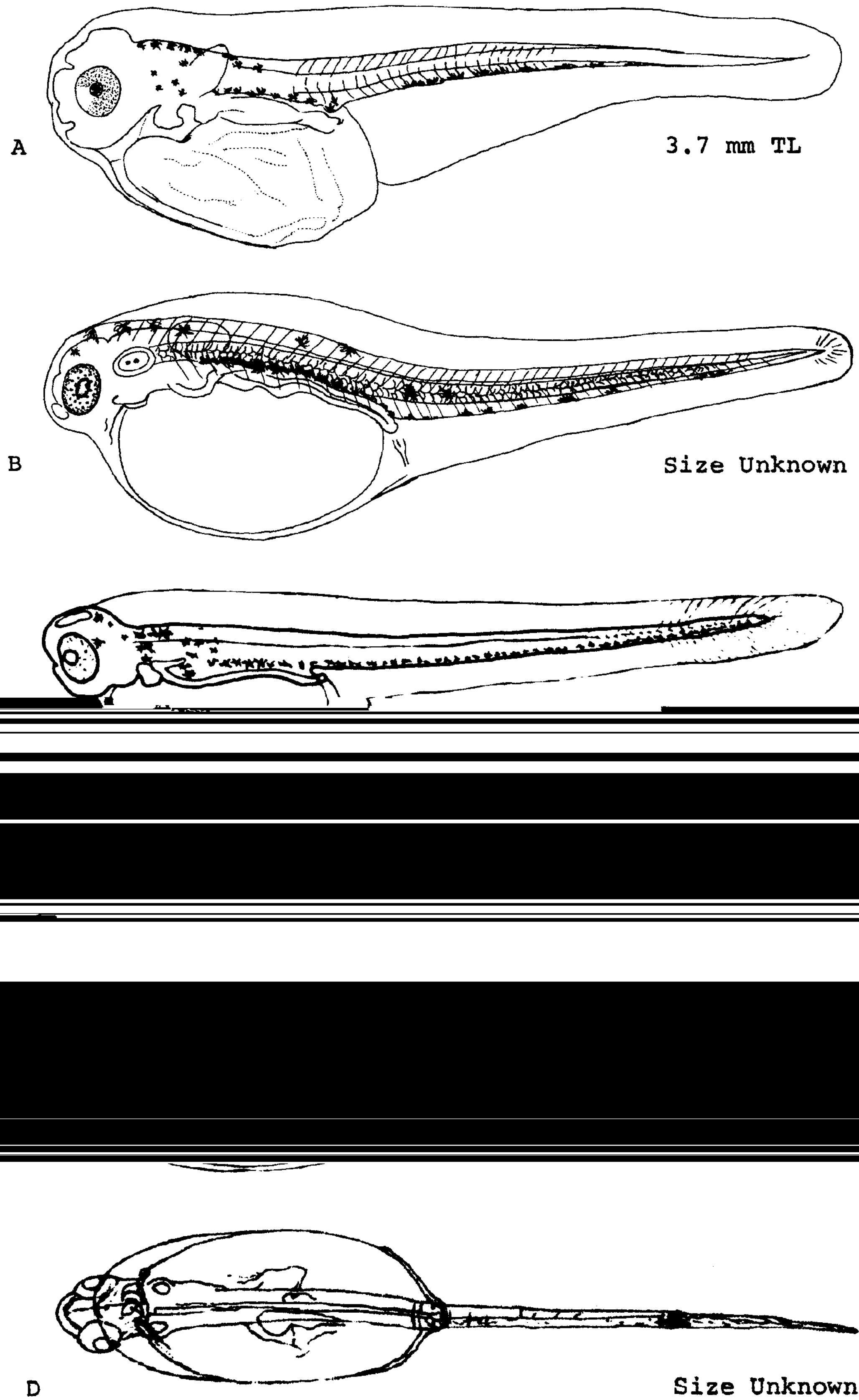
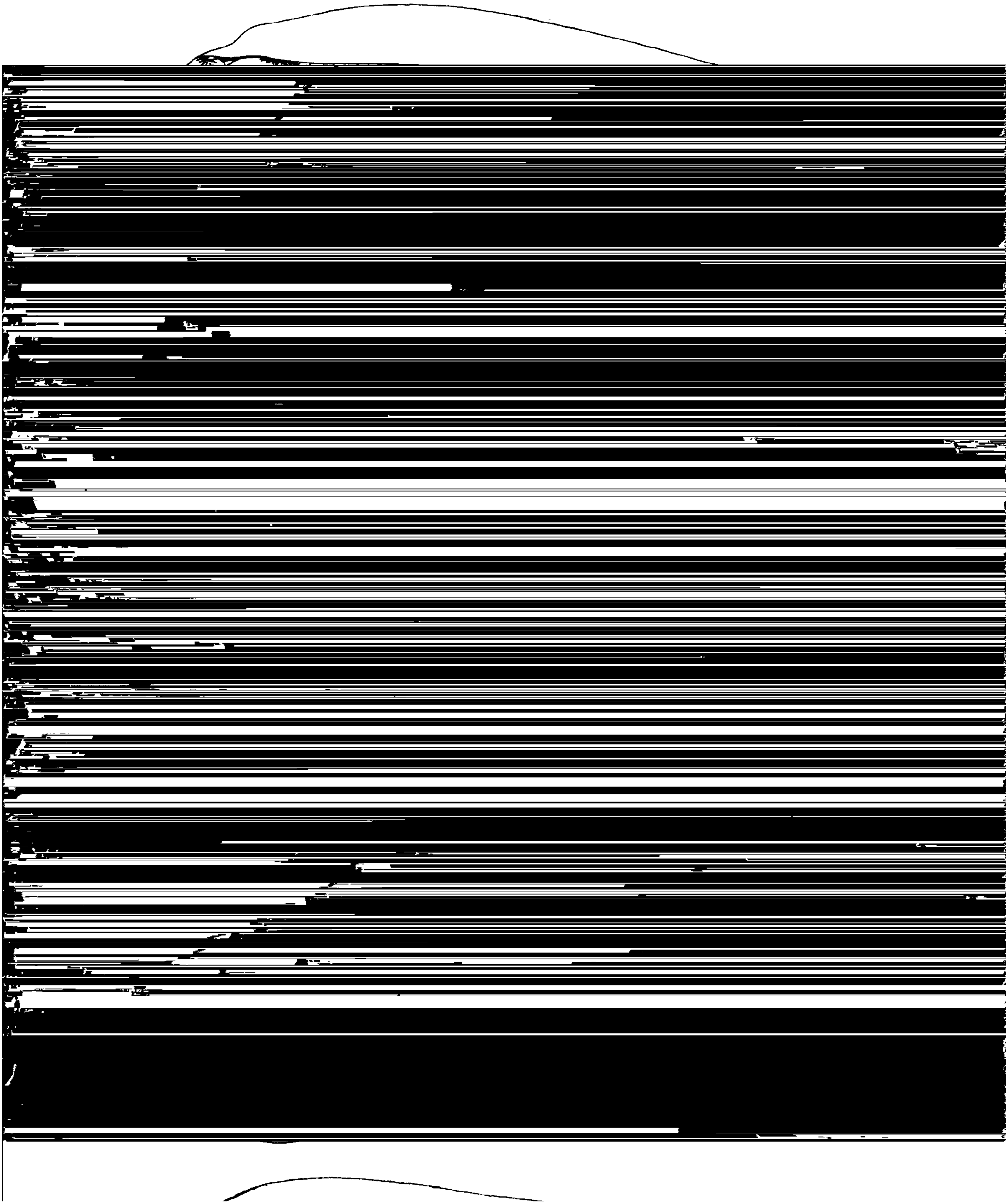
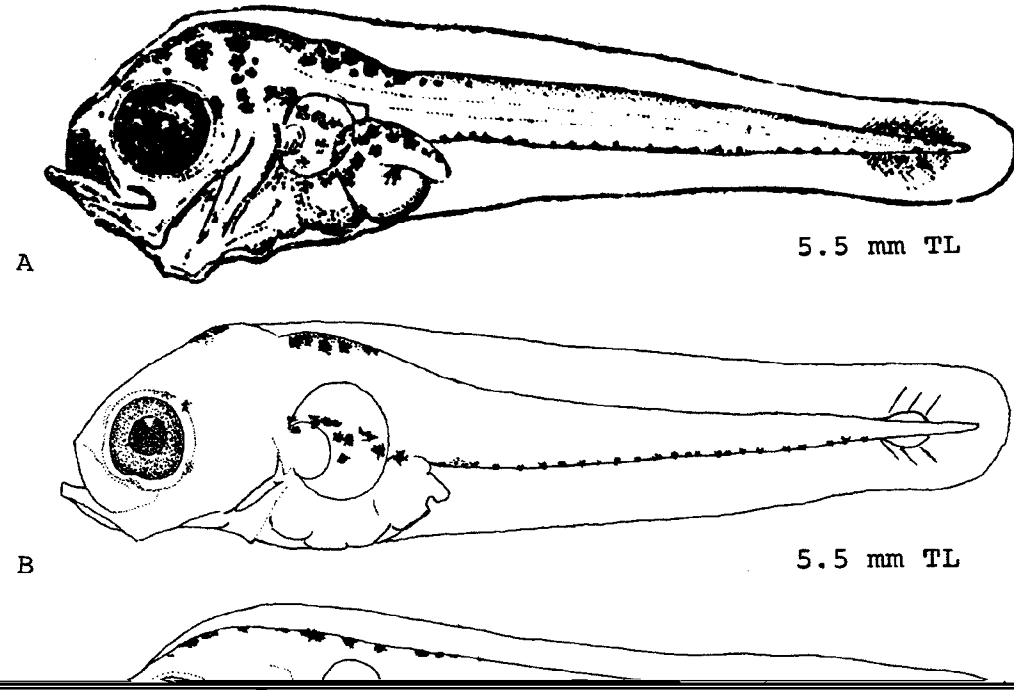


Fig. 160. *Melanogrammus aeglefinus,* Haddock. A. Yolk-sac larva, 3.7 mm TL. B. Yolk-sac larva, size unknown, eye poorly pigmented, caudal rays developing. C. Yolk-sac larva, size unknown apparently just hatched, yolk reduced. D. Yolk-sac larva, ventral view, size unknown. (*A, Dannevig, A., 1918: pl. 3, Tamiko Karr, delineator.*




A
5.5 mm TL
B
5.5 mm TL

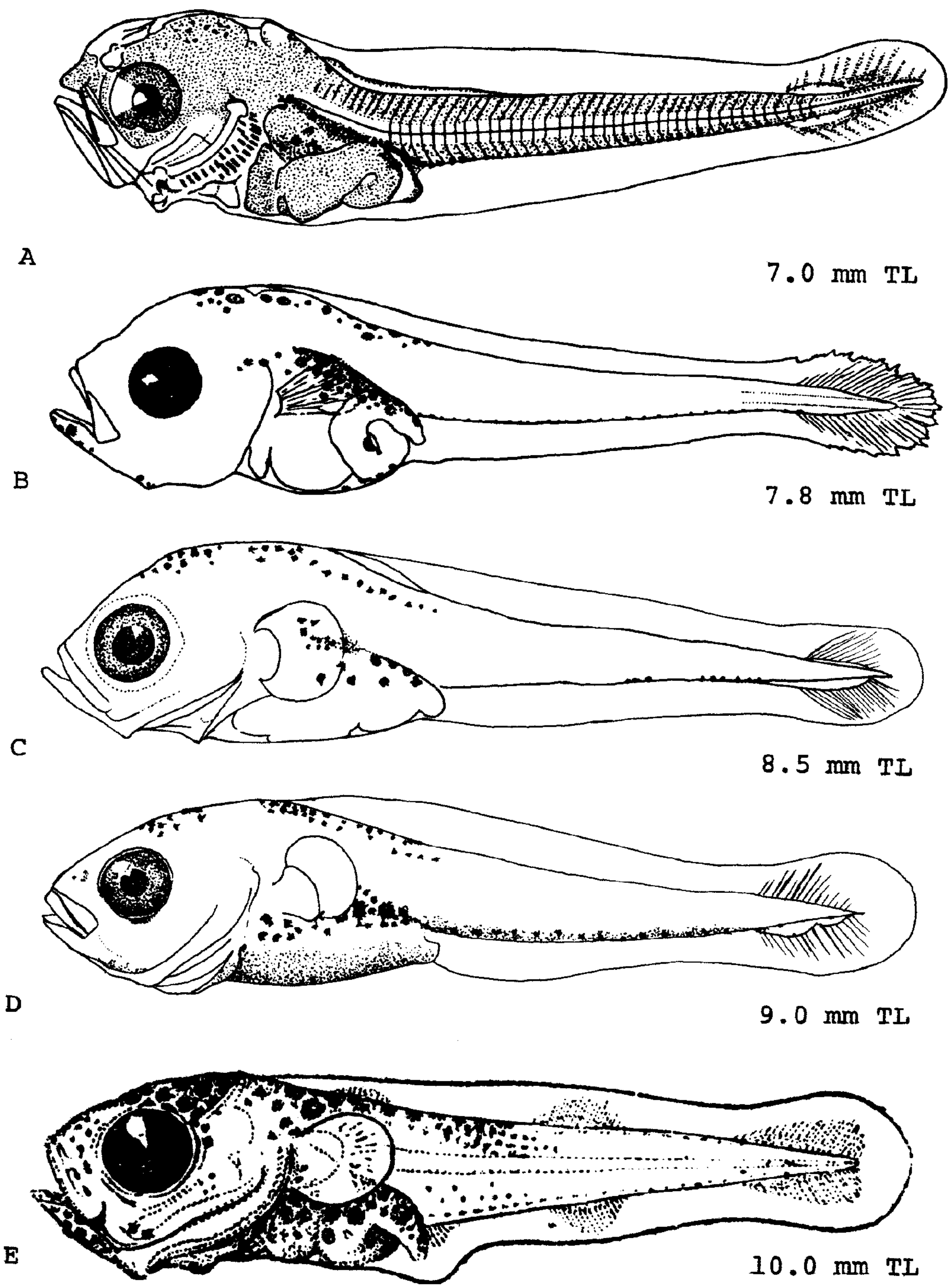
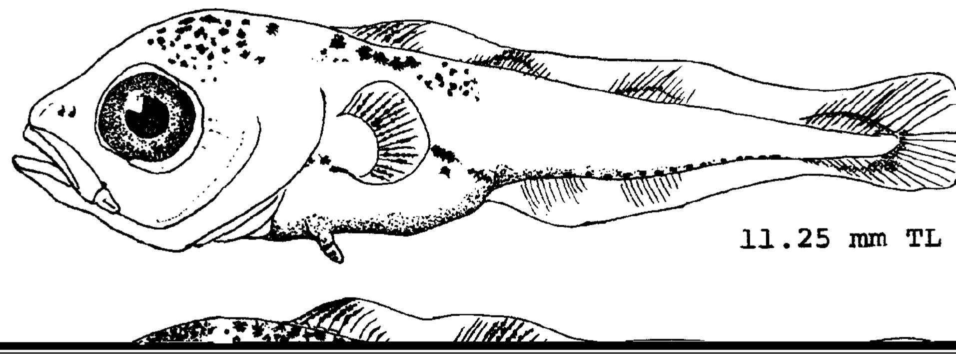
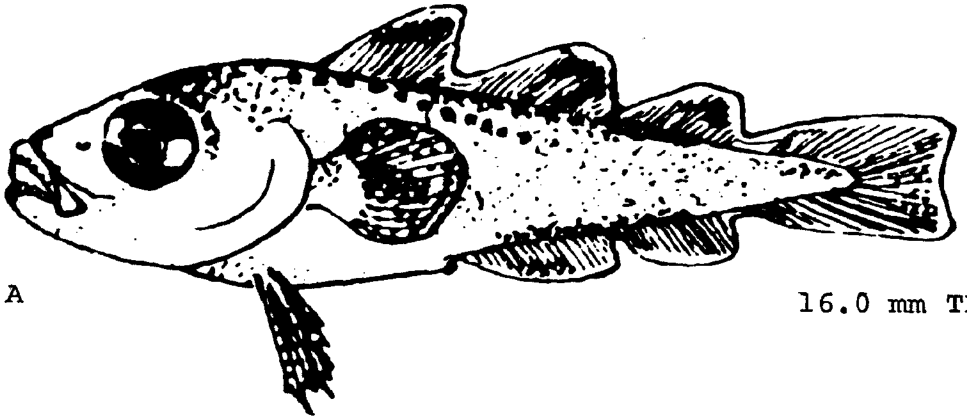


Fig. 163. *Melanogrammus aeglefinus*, Haddock. A. Larva, 7.0 mm TL. B. Larva, 7.8 mm TL, well formed rays in caudal fin, finfold reduced. C. Larva, 8.5 mm TL. D. Larva, 9.0 mm TL. E. Larva, 10.0 mm TL, earliest indications of dorsal and anal rays. (*A, Dannevig, A., 1918: pl. 3, Joan Ellis, delineator. B, Miller, D., 1958: 26. C, Schmidt, J., 1906: fig. 18, Tamiko Karr, delineator. D, Schmidt, J., 1905: pl. 2, Tamiko Karr, delineator. E, Rass, T. S., 1949: fig. 27.*)



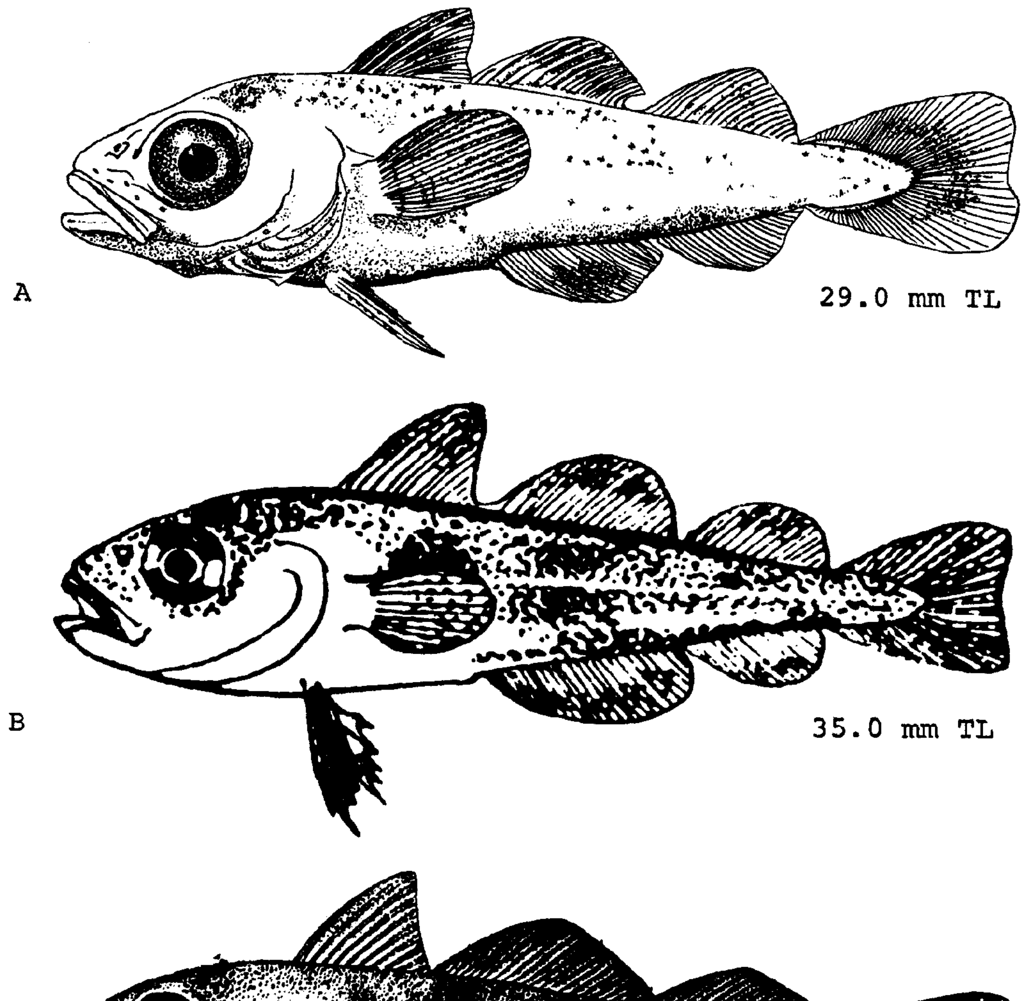
A

11.25 mm TL



A

16.0 mm TL


A
29.0 mm TL
B
35.0 mm TL

The gas bladder probably becomes functional at ca. 4.0 to 9.0 mm, and may bring larvae of less than 8.0 mm toward the surface.[121]

Pigmentation: Generally yolk-sac larval pigment persists to ca. 8.0 to 10.0 mm, thereafter pigment becomes diffuse and resembles that of cod and pollock.[12,44] In larger individuals (ca. 8.0 to 20.0 mm) posterodorsal and preanal pigment weak or absent, pectorals and pelvics strongly pigmented.[67] Shortly after absorption of yolk, diffuse orange or yellow pigment (live or newly preserved specimens) on head, anterior part of body, and in visceral region.[87,96]

At 6.75 mm a patch of large, round chromatophores on occiput and a double row of chromatophores extending back from this patch to just behind posterior margin of pectorals; double row continued, but much fainter, from this region to a little beyond level of anus; a row of small chromatophores ventrally from anus to hypural elements in tail; in life yellowish brown pigment on neck, abdominal region, and, to some extent, in anterodorsal streak.[72]

At ca. 8.0 mm roof of peritoneum densely pigmented.[22]

At 9.0 mm occiput and abdominal pigment as before; preanal pigment weak, consisting of ca. 5 small dots; a small branch of dorsolateral pigment developed above anus.[20]

At 10.0 mm pectorals sometimes with strongly marked stellate chromatophores; pigment otherwise as in previous stage; in life yellowish brown pigment on nape and anterior part of back.[20]

At 11.25 mm $D._1$ and $D._2$ with strong black pigment between rays, also chromatophores between rays of distal end of pelvic fin.[20]

At 13.5 mm pigment developed in pectorals, otherwise pigment essentially as before, but sometimes with scattered chromatophores on sides.[20]

At 15.0 mm occipital, abdominal, anterodorsal, and anterodorsolateral pigment well-developed, dense; no pigment in posterodorsal region; behind pectorals an anterodorsal branch of pigment (from which adult pattern will develop; A. pigmented.[20]

PREJUVENILES

Size range ca. 28.0 (based on minimum size at descent to bottom)[17] to 43.0 mm (body adult-like),[72] but limits highly subjective, based more on morphology than behavior, and not taking into account that western Atlantic populations do not begin descent to bottom until 90.0 to 130.0 mm.[34,85,90]

Scales developed at 39.0 mm.[20]

Pigmentation: At 29.0 mm conspicuous in pelvic fins.[20]

At 35.0 mm pigment on body beginning to concentrate in spots; characteristic black spot of adult developing below $D._1$; in some specimens pigment developed in $A._2$[20]

At 39.0 mm sides silvery.[20]

At 43.0 mm dense pigment on sides arranged in three distinct blotches, the anteriormost of which is the developing dark spot of the adult.[72]

JUVENILES

Minimum size 43.0 mm.[72]

At 53 mm pelvics proportionately shorter than in earlier stages (probably reflecting change from pelagic life); shorter still at 100 mm. At 80 mm 2nd ray of pelvic fin elongate, but failing to reach vent.[20]

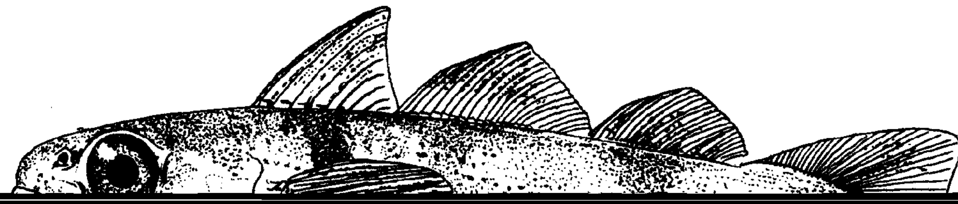
Pigmentation: Shoulder spot evident at 45–50 mm.[142]

At 53 mm dark shoulder spot well-developed; pectorals with yellowish brown hue and with black spots along edges; pelvics pale, but with few melanophores in center; head and body minutely and uniformly dotted with black; eyes with silvery sheen.[20]

At 80 mm body with coppery sheen; pectorals, pelvics, and first anal with black pigment.[20]

AGE AND SIZE AT MATURITY

In North Sea mature at an average of about 3 years;[2,66,102,138] 10% of females at age 2, 75% at age 3, 95% at age 4, 99% at age 5; 60% of males at age 2, 95% at age 3, 99% at age 4, 100% at age 5.[119] North of North Sea



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Microgadus tomcod (Walbaum), Atlantic tomcod

ADULTS

D. 1, 11–15; D. 2, 15–20; D. 3, 16–23;[5,7,11] A. 1, 17[33] (a count of 12[11] is questioned, JDH)–23; A. 2, 16–20;[5,11] P. 16–19;[43] gill rakers 16–21;[5,11] branchiostegal rays 7; vertebrae 53–57.[43]

Proportions as times in TL: Head 4.75, depth 5;[7] as percent TL, head 20.1–22.2.[43] Proportions as times in HL, eye 5.5–7.0;[7] as percent HL, eye 14.8–19.7, snout 33.3–38.5, interorbital width 29.4–33.3.[43]

Body moderately elongate,[7] slender,[11] only slightly compressed; snout rounded; eye small; upper jaw projected.[7] Numerous fine teeth on jaws and vomer;[43] mouth extended to pupil.[33] A short barbel on chin.[27] Lateral line moderately arched over pectoral fin.[43] All vertical fins, especially caudal, rounded;[27] origin of first dorsal over middle of pectorals or further back; pelvics narrow, tapering, and with one filamentous ray;[11] vent under interval between first and second dorsal.[33]

Pigmentation: Brown, olive brown, muddy green, olive, or yellowish brown above with green or yellow tinges; mottled with indefinite black spots or blotches which may extend on to pectorals, anals, and pelvics. Lateral line white. Lower sides with decidedly yellowish cast in larger fish. Belly grayish or yellowish white and without spots. Dorsal and caudal same as back; anal pale at base, olive at margin.[5,7,11,43]

Maximum length: Ca. 380 mm,[2,5] or possibly 447 mm.[40]

DISTRIBUTION AND ECOLOGY

Range: Southern Labrador[43] to Virginia.[28]

Area distribution: Coast of New Jersey;[9,20] up Delaware River to vicinity of Philadelphia;[17,19] near Ocean City, Maryland;[16] at mouth of Chesapeake Bay.[21,25,28]

Habitats and movements: Adults—an anadromous, inshore, bottom dwelling species[2,11,34] found along shores, in brackish estuaries, and freshwater rivers,[5,31] inlets tributary to bays,[1] streams,[11,22] lakes,[35] and shallow, muddy harbors;[2,11] sometimes over eelgrass beds.[35] Landlocked populations are known in Nova Scotia and Quebec.[6,28] In winter, in only a few inches of water, slush, and floating ice, and sometimes shelter under ice.[5,28] Maximum recorded depth, 2.7 m,[28] but possibly to 3.6 or 5.5 m. Not more than 1.6 km beyond headlands.[11] Recorded at salinities of 0.0–31.4 ppt,[37] and can withstand abrupt salinity changes.[38] Recorded from −1.2 C or slightly lower[36] to ca. 25.5 C.[40]

Anadromous,[6,34] coming inshore[29] and entering streams[14] and rivers[7,15] in October,[8] November and December.[23,29] Return to coastal areas primarily in late January.[15] In the United States may ascend rivers in winter for at least 95 km,[10,13] and, in former times, up to ca. 225 km (at Albany, New York).[32] In St. Lawrence River undertake regular seasonal movements: upriver, appearing at Quebec City toward end of September and at Lake Peter in early December; downriver from February to May.[40] In Maritime Provinces and Gulf of Maine no offshore movements throughout year; south of Cape Cod move slightly offshore into deeper water in spring, returning in autumn. Enter Weweantic Estuary, Massachusetts, in autumn and from October to May move with tide, these movements apparently associated with spawning and feeding; move into deeper water at mouth of estuary by late June. In New Jersey move inshore in September and October, apparently in response to drop in temperature to 17.2 C.[2,11,35]

Larvae—in surface collections at Woods Hole from December or January to April (with earliest occurrence varying from year to year);[14,28] in Mystic River, Connecticut, larvae of unspecified size mostly at bottom;[3] also, in same river, pelagic stages and planktonic larvae from January to early April with greatest concentrations up river and in channels.[28] Yolk-sac larvae apparently show preference for bottom waters during the day.[41] Reported from 0.5 to 30.0 ppt, with average surface salinity of 12.0 ppt and average bottom salinity of 22.5 ppt,[28] and 1.1[44] to 11.7 C, with average surface temperature of 5.8 C and average bottom temperature of 5.1 C.[28] Larvae 44 hours old and older were able to withstand temperature increases of at least 14.4 C above an ambient temperature of 1.1 C for 30 minutes.[41]

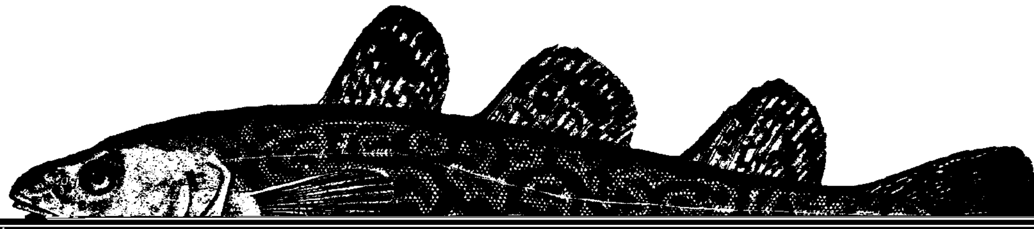
At hatching swim toward surface, fall back head first.[28] Larvae may change to benthic habitat at 10 to 20 mm.[35]

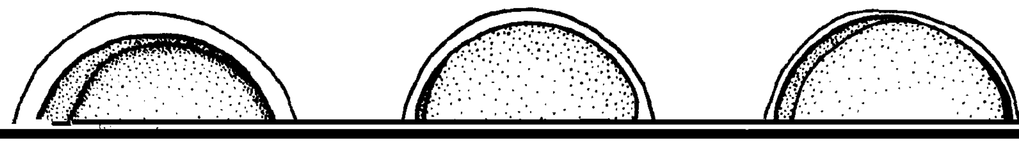
Juveniles—generally recorded from shoal areas, in coves near mouths of rivers, and on subtidal flats; found over bottoms of eelgrass, sand, and silt.[35] Young-of-the-year may remain in brackish river water for some months;[7] also specimens ca. 71–110 mm long along low tide line on Connecticut beaches. Possible maximum temperature 25.8 C; possible maximum salinity, 26.3 ppt.[26]

Specimens 24 to 76 mm long are reported to approach shores from late May to June in New England.[26] Larger juveniles probably undergo fall and winter movements with the adults.[35]

SPAWNING

Location: Variously reported from along shores,[22] at mouths of streams,[2,11] at head of tide,[7] in creeks among





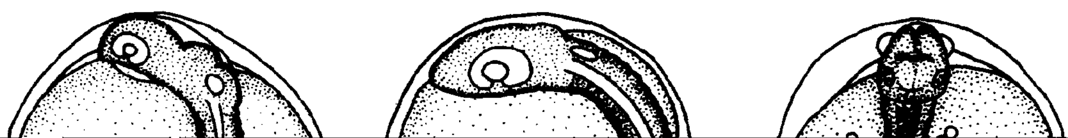
emergent cordgrass (*Spartina alterniflora*),[35] and, in New York harbor, around docks and in weeds;[12] typically over sandy[40] or gravel bottom,[43] and usually associated with ice.[28,40]

Season: November through February[2,12,29,30] with peak activity in December[4,15,22] or January.[5,11,28]

Time: Unknown, but running ripe males and females collected at night.[28]

Temperature: Running ripe males and females at 0 C;[28] spawning observed at 2.5 C; bottom temperature during spawning period 1.0 to 5.0 C.[35]

Salinity: In freshwater, at least in landlocked populations. Otherwise run into freshwater, but spawn exclusively in estuaries. Ripe males and females have been taken in water having a salinity of 15.7 ppt. Optimum salinities probably correspond to those salinities which permit greatest sperm activity: 1 or 2 to 13 or 14 ppt. Salinity at the moment of fertilization is probably more important than average values during the incubation period.[2,28] Reports of spawning at any salinity[18] and in both brackish and salt water[5] are probably in error since sperm are not active at salinities greater than 19 or 20 ppt.[28]



Fecundity: 5075[4] to 75,000;[12] estimated averages vary from 9000 to 30,000.[2,4,5,12,41] Fecundity increases with size: at ca. 175 mm, 6000; at ca. 225 mm, 14,000; at ca. 350 mm, 65,780.[41]

EGGS

Location: Demersal;[41] under experimental conditions initially attached to each other in large sheets, rarely attached to rearing vessel;[42] also reported attached to sand and gravel on bottom.[43]

Ovarian eggs: In October, 0.6 mm in diameter, in December, 1.4 mm; ripe ovarian eggs 1.4–1.5 mm in diameter.[4]

Fertilized eggs: Spherical[7] or somewhat oval; diameter 1.39[42]–1.7 mm,[12] reported averages 1.47[42] and 1.66;[2] reported as nonadhesive by some authors,[12,28,29,30,39] otherwise adhesive,[3] adhering to one another but rarely to substrate; adhesiveness lost within one to five days after fertilization in some samples, retained until time of hatching in others;[42] according to some authors, oil globule (or globules) absent,[5,23] in some specimens, however, 3–12 small oil globules evident after gastrulation, but not evident in all batches of eggs or all eggs within a single batch, and with number possibly increasing as development proceeds[42] (a report of an apparently single "distinct oil globule"[46] is questioned, JDH).

EGG DEVELOPMENT

216 hours (9 days)	Head distinct, embryo around one half of yolk diameter, blastopore small.
240 hours (10 days)	In some specimens blastopore nearly closed, eyes just forming; in others Kupffer's vesicle well-developed, optic vesicles large. In this and subsequent stages minute oil globules may be present.
264 hours (11 days)	Optic vesicles somewhat elongate, both blastopore and Kupffer's vesicle evident in some specimens, somites present or absent.
312 hours (13 days)	Somites evident in all specimens, brain divisions forming.
336 hours (14 days)	Otocyst and lens forming, tail still attached but peaked up over yolk, 21–23 somites.
360 hours (15 days)	Embryo sunken into yolk, giving yolk a bilobed appearance, tail free, choroid fissure closing, 22–24 somites.
384 hours (16 days)	Number of somites noticeably increased, uncountable; choroid fissure closed; notochord hyaline; otoliths developed; length of tail noticeably increased.
408 hours (17 days)	Heart well-developed, number of somites and length of tail increased.
504 hours (21 days)	Pigment evident in thoracic region (also, rarely, on head).
600 hours	Heartbeat established; pigment spread

YOLK-SAC LARVAE

Minimum reported length, 4.12 mm,[44] although average

[illegible]

extended on to head;[42] in other yolk-sac larvae dorsal finfold terminated at point about half way between anus and posterior border of otic capsule. Pelvic finfold car-

[illegible]

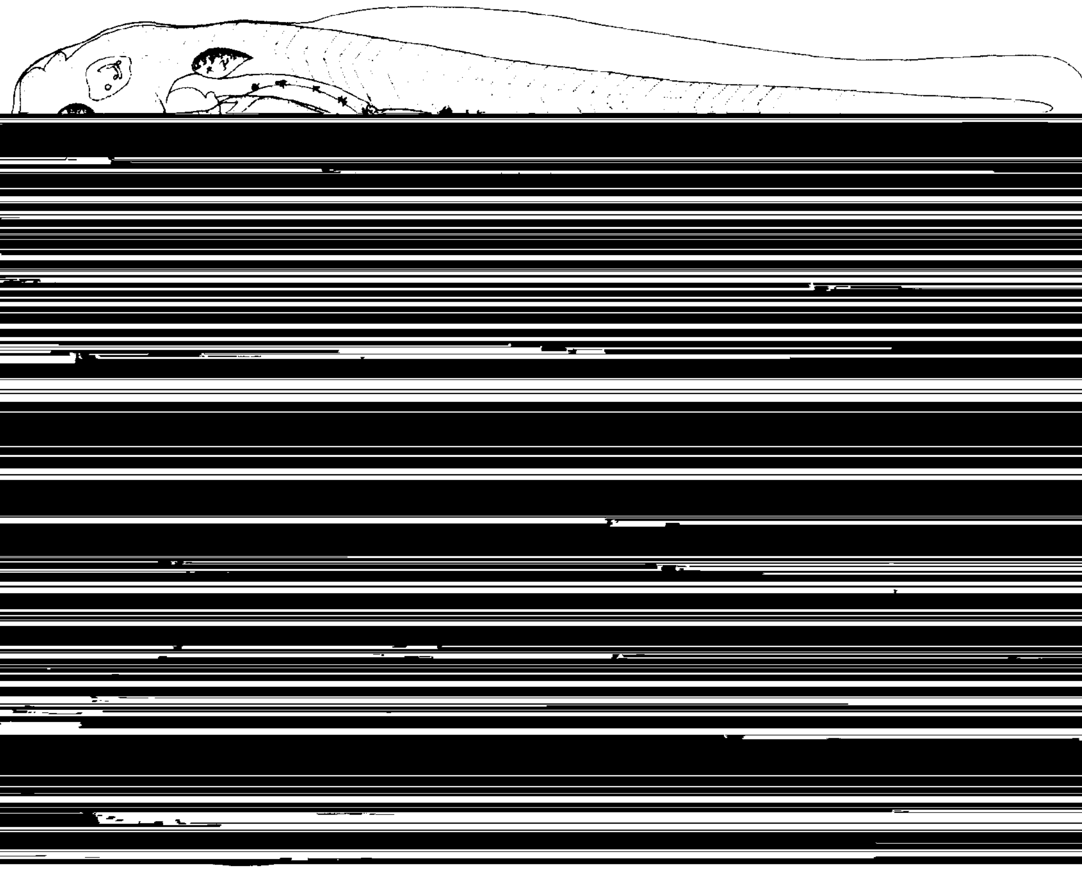


Fig. 172. *Microgadus tomcod,* Atlantic tomcod. A. Yolk-sac larva, newly hatched, 4.7 mm TL, showing pigment on yolk sac, body, and gas bladder. (*A, Original drawing, J. D. Hardy, Jr.*)

3 disjunct rows of pigment ventrally beyond anus, and pigment developed along mid-dorsal line. In the largest recent hatchling pigment similar except ventral pigment rows more or less continuous, and few large stellate melanophores on yolk.[42] In a hatchling 4.9 mm long, pigment as described above, also on eye and gas bladder

At 6.5–7.95 mm 4 melanophores develop on isthmus, as well as on ventral ends of developing cleithra. All specimens 7.5 mm long or longer with lower jaw pigmented. At 6.00–6.45 mm one or a pair of small stellate or reticulated melanophores on dorsal wall of intestine just above the anal opening. Melanophores at the angle between

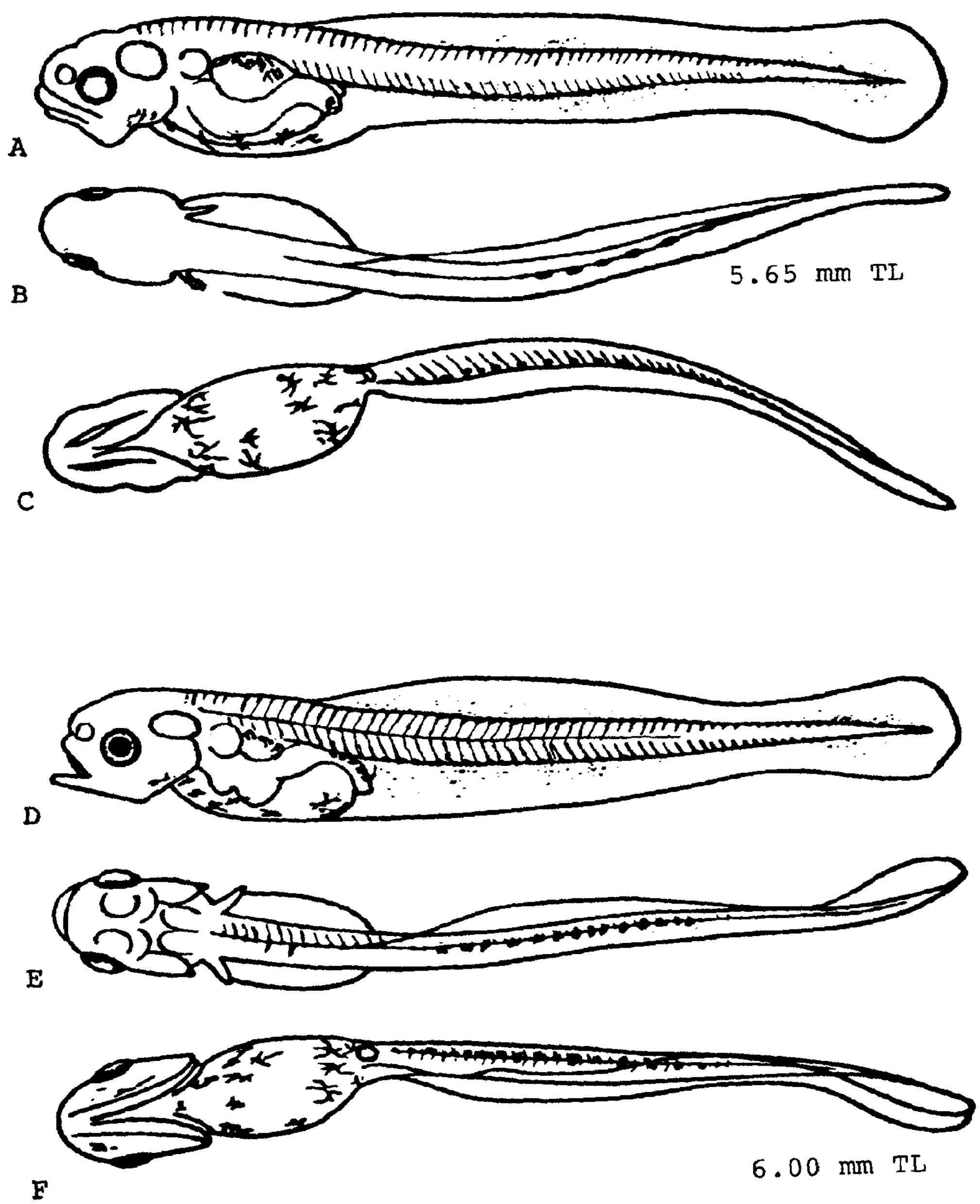
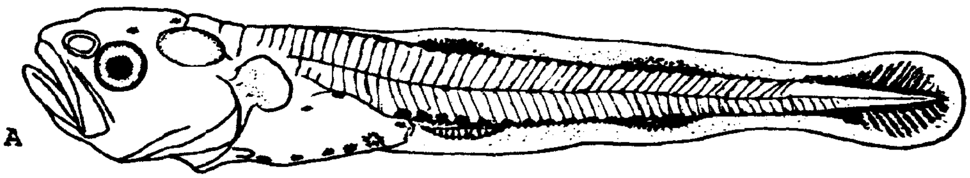


Fig. 173. *Microgadus tomcod*, Atlantic tomcod. A, B, C. Yolk-sac larva, 5.65 mm TL, lateral, dorsal, and ventral views. D, E, F. Larva, 6.00 mm TL, lateral, dorsal, and ventral views. (*A-F, R. A. Booth, 1967: pls. 1–3.*)

A



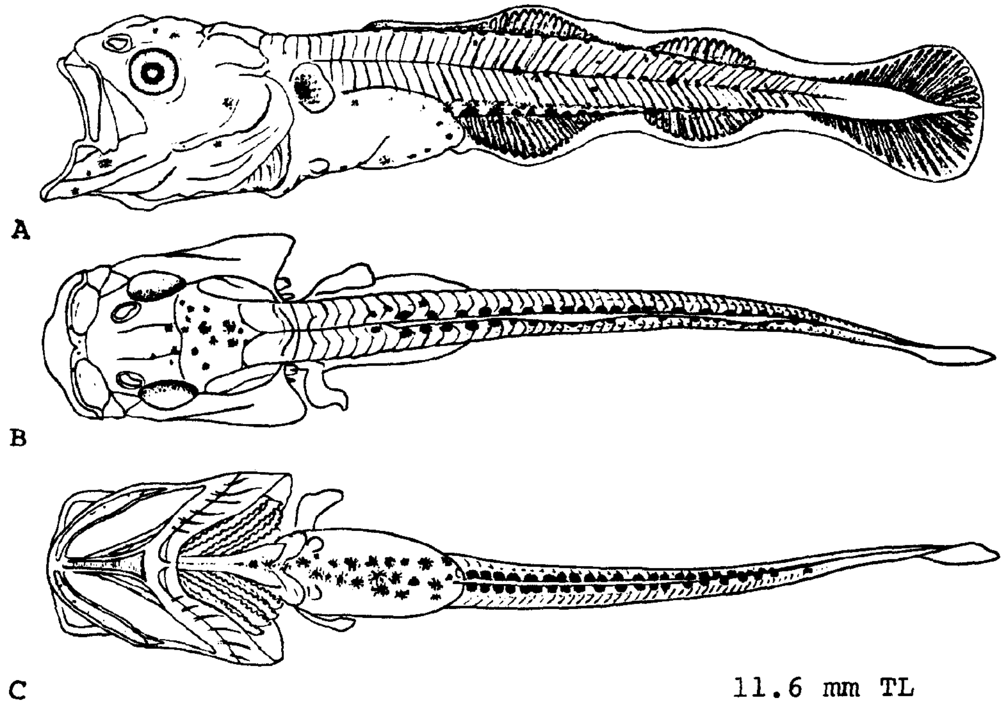


Fig. 176. *Microgadus tomcod,* Atlantic tomcod. A, B, C. Larva, 11.6 mm TL, lateral, dorsal, and ventral views (note presence of pelvic buds). (*A-C, Booth, R. A., 1967: pl. 4.*)

about 11 narrow blotches, sometimes forming chain-like pattern, over back, these extending ventrad below the mid-lateral region; pigment on head increased forming a prominent blotch on crown; pigment evident on first dorsal, and in all pigmented median fins melanophores have migrated outward from fin bases.[42]

AGE AND SIZE AT MATURITY

Minimum age at maturity: 11 to 12 months in Hudson River,[45] although apparently at end of third year or during fourth year in Quebec.[40] Minimum length at maturity: Smallest female 170 mm.[4]

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Phycis chesteri Goode and Bean, Longfin hake

ADULTS

D. 1 9–10;[4] D. 2 54[3]–59;[2] A. 47[3]–56;[4] C. 5+18–21+5; P. 16–18; V. 3; scales ca. 90–91; scales above lateral line 7, below ca. 28;[10] gill rakers, 4 or 5 (JAM)+14–15,[2] total 21;[3] branchiostegals 7;[10] vertebrae 49.[3]

Proportions as times in TL: Greatest depth 6; head length 5.5.[4] Proportions as percent of head length: eye 31.7; interorbital distance ca. 13.4.[3]

Body elongate; head pointed; upper jaw projecting; gape extended to pupil; a small barbel,[4] about 1/3 diameter of orbit,[12] on lower jaw. Lateral line broadly arched in first half, broken in posterior half.[4] Third dorsal filament greatly produced,[2] 5 times longer than next longest ray; pelvics very long, filamentous.[4]

Pigmentation: Olive black above, sides gray (JAM), belly silvery white; fins same color as back and with dusky markings on edges.[4] In alcohol brown on back, muddy or reddish white below.[3]

Maximum length: Ca. 382 mm.[4]

DISTRIBUTION AND ECOLOGY

Range: South of Laurentian Channel, Newfoundland[3,4] to off Dry Tortugas, in the Gulf of Mexico (JAM).[2]

Area distribution: Off New Jersey;[6] east of Cape Charles, Virginia, but only beyond the 183 m depth contour.[7]

Habitat and movements: Adults—bottom species found at depths of 58 to 1335 m (but usually at 366 to 457 m);[1,3,8,9,10] larger individuals found in deeper water.[11,12]

Larvae—specimens up to 10.0 mm long from surface to 50 m;[11,12] also reported from average tow depth of 435 m.[7]

Juveniles—specimens 25[11] to ca. 125 mm long at surface;[12] specimens 90 to 320 mm long between 183 and 366 m.[5]

SPAWNING

Season: Probably in fall.[3,4]

Fecundity: No information.

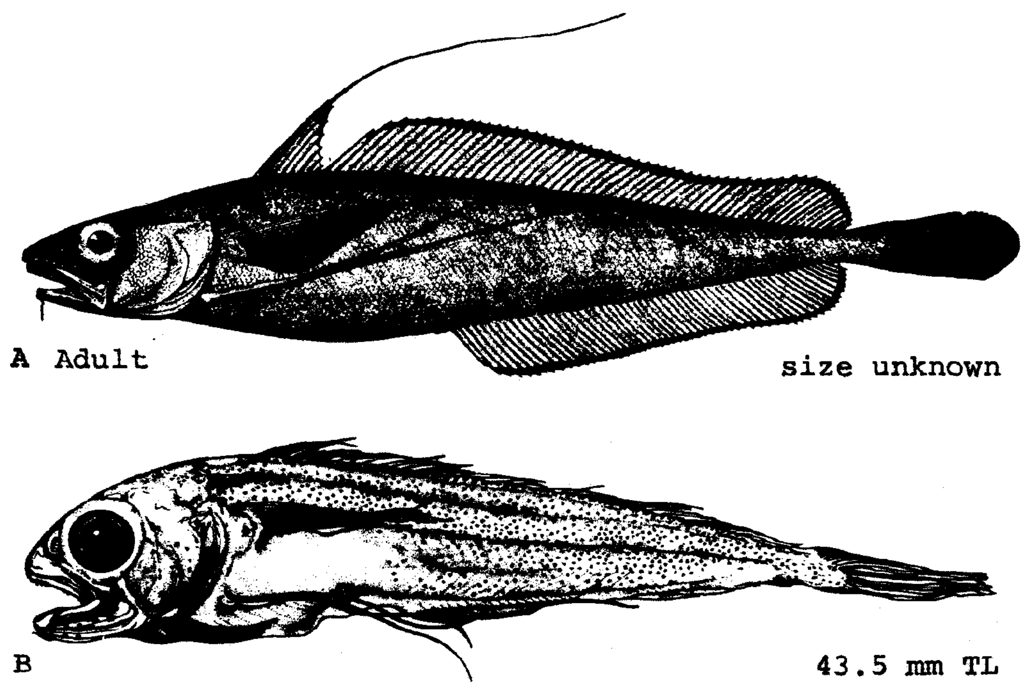

Fig. 178. *Phycis chesteri*, Longfin hake. A. Adult, size unknown. B. Juvenile, 43.5 mm TL. (A, *Jordan, D. S., and B. W. Evermann, 1896–1900: fig. 903. B, Original illustration, Elizabeth Ray Peters.*)

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

JUVENILES

Size described, 43.5 mm TL.

At 43.5 mm TL, barbel formed, teeth well-developed in upper jaw (JDH).

Pigmentation: Pigment developed on both jaws, in opercular region, in two indefinite blotches on snout and top of head, and in region of cleithrum. Region of abdominal cavity grayish and apparently unpigmented; body otherwise spotted with large, widely spaced melanophores, especially above mid-lateral line. One branch of lowermost pelvic ray with a long brown blotch; fins otherwise without pigment (JDH).

AGE AND SIZE AT MATURITY

No information.

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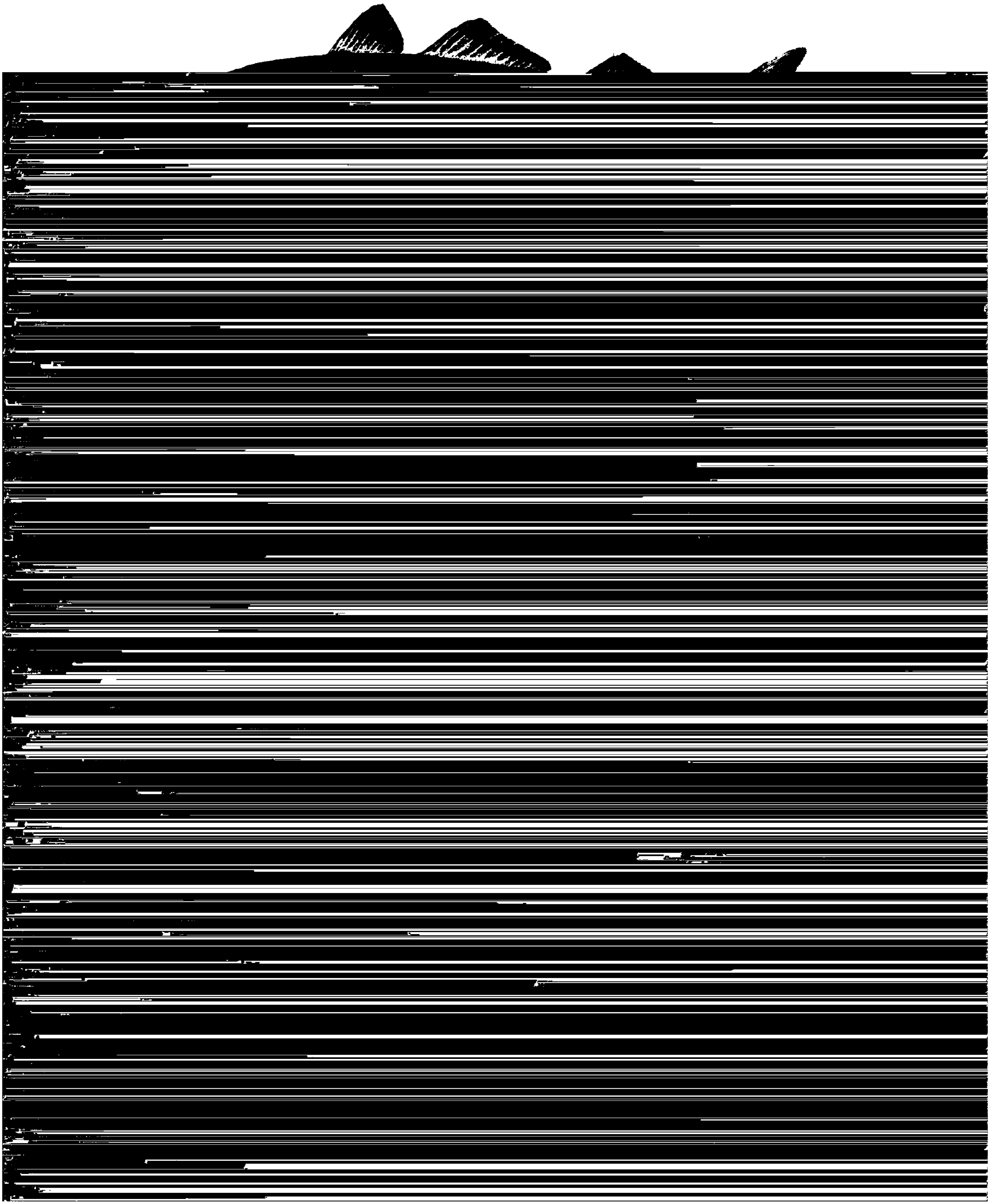
Pollachius virens (Linnaeus), Pollock

ADULTS

D.$_1$ 21[47] (or possibly 9[32])–15[73] (w. Atlantic 13–14[14,20]), D.$_2$ 17[43] (or possibly 14[32])–26[46] (w. Atlantic 21–22[14]), D.$_3$ 19[14,47,73]–24[12] (w. Atlantic 24–28[14]); A.$_1$ 21[32]–30[73] [redacted]

cies[34,60,68,72] found at bottom, and midwater depths as well as at the surface[12,19,28] where it sometimes breaks water like mackerel.[65] Usually at edges of shoals and banks,[1] also close inshore[27] as in "tide rips."[25] Reported from fjords in Greenland.[55] Typically over stony bot- [redacted]



contour.[31] Specimens 38 and 40 mm long at 8.0–15.5 C.[82] About 200 mm specimens down to 0 C, and seldom above 15.6 C.[68] Specimens 38–40 mm long at ca. 31.5 ppt.

At 25[9,56] to 50 mm,[28,59] swim to bottom (and apparently shoreward), but may not arrive inshore until 60 mm long.[15] In American waters the bottom stage begins after 3 months or more. Although Bigelow and Schroeder believed that young pollock descend in practically the same [redacted]

December[15,56] to June[73] with peak activity occurring in February and March.[9,49,50,59,77] Spawning has been observed in aquaria (in Europe) in early May.[67] In Iceland mid-February[19,39] to early May,[40] with maximum production in April.[74]

Temperature: Spawning occurs on a falling temperature, and the entire water column must cool to 8 or 9 C before spawning begins.[68] Temperature range in American [redacted]

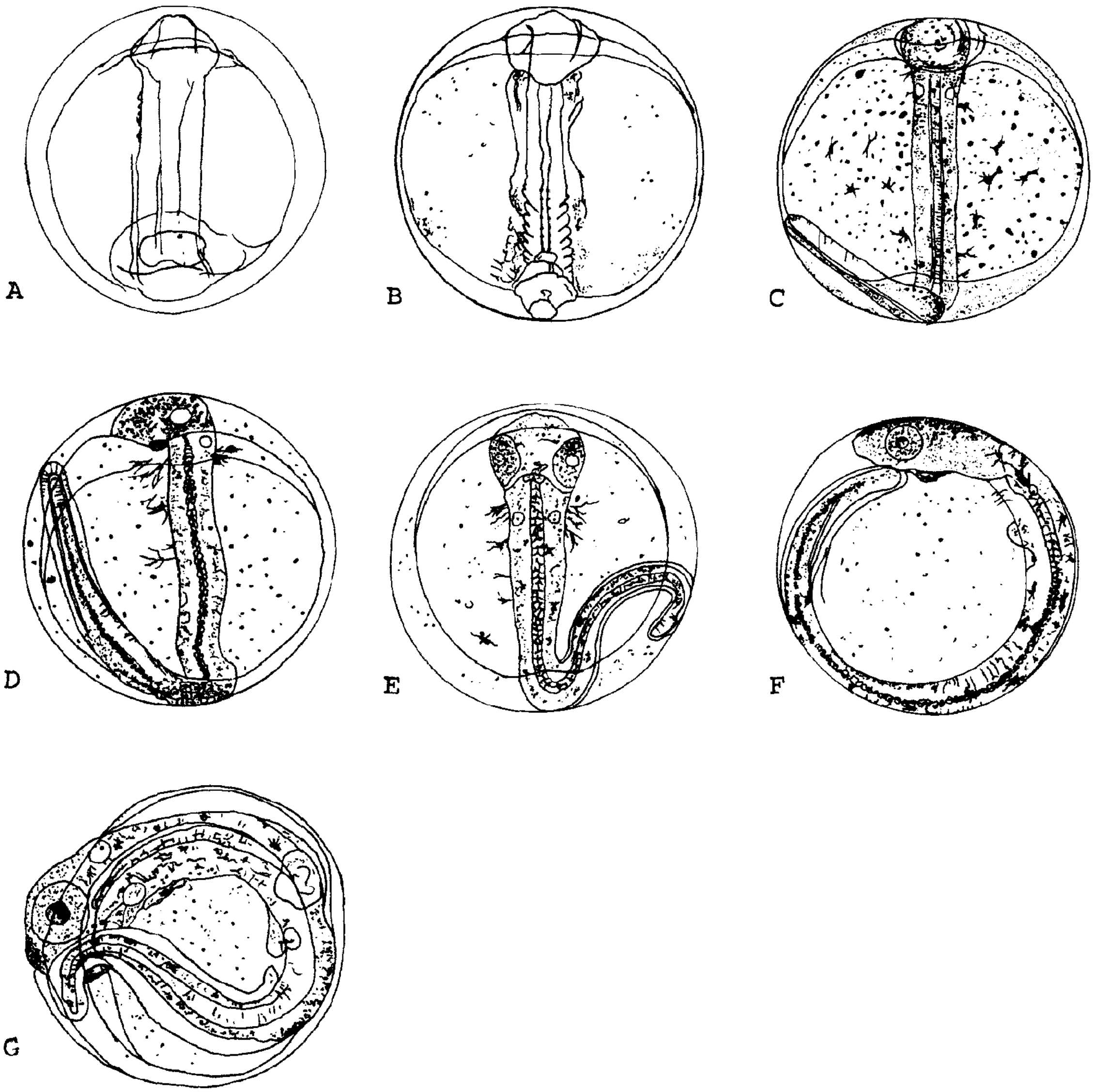


Fig. 180. *Pollachius virens*, Pollack. A. 4 days after fertilization, blastopore closing. B. 5 days, blastopore closed, somites forming. C. 7 days, dense pigmentation on yolk. D. 8 days, pigment forming on yolk. E. 8 days, showing variation in pigment, less on yolk, more on body. F. 9 days, pigment in conspicuous series on body. G. Age unknown, hatching. (*A, G, McIntosh, W. C., 1893: pl. 9, Tamiko Karr, delineator.*)

	some melanophores in median region behind eye.
7th day.	Number of somites increased, lenses distinct, Kupffer's vesicle still evident, entire body covered with pigment.
8th day.	Tail elongate, black pigment more distinct, some stellate chromatophores evident.
9th day.	Otoliths developed, pigment somewhat irregular.
10th day.	Otocysts broadly ovoid, notochord cellular, pectoral buds evident, gut distinct.
11th day.	Heart contractions begun, tail nearly around yolk, melanophores generally enlarged and 8 or 9 melanophores developed on head.
12th day.	Hatching begins.[80]

Development at unspecified temperature (M'Intosh series 2):[79]

3rd day.	Blastopore still open, but reduced;

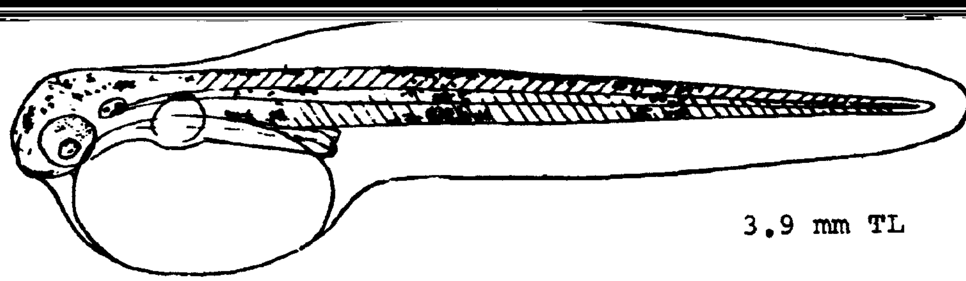
	optic vesicles formed; perivitelline space variable within the series.
4th day.	Blastopore closed, Kupffer's vesicle formed, myomeres evident, yolk with faintly granular appearance, pectoral buds large.
6th day.	Melanophores over yolk, and indications of similar pigment on body.
7th day.	Chromatophores greatly increased, but pigmentation variable.
8th day.	Sides of body and yolk with conspicuous melanophores, tip of tail extended to head.[79]
9th day.	Hatching begun.[33]

Comments on incubation: Eggs develop best from 3.3 to 8.9 C.[68]

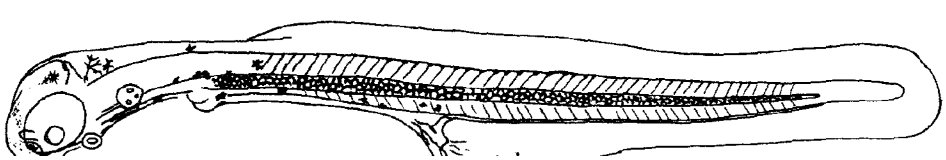
YOLK-SAC LARVAE

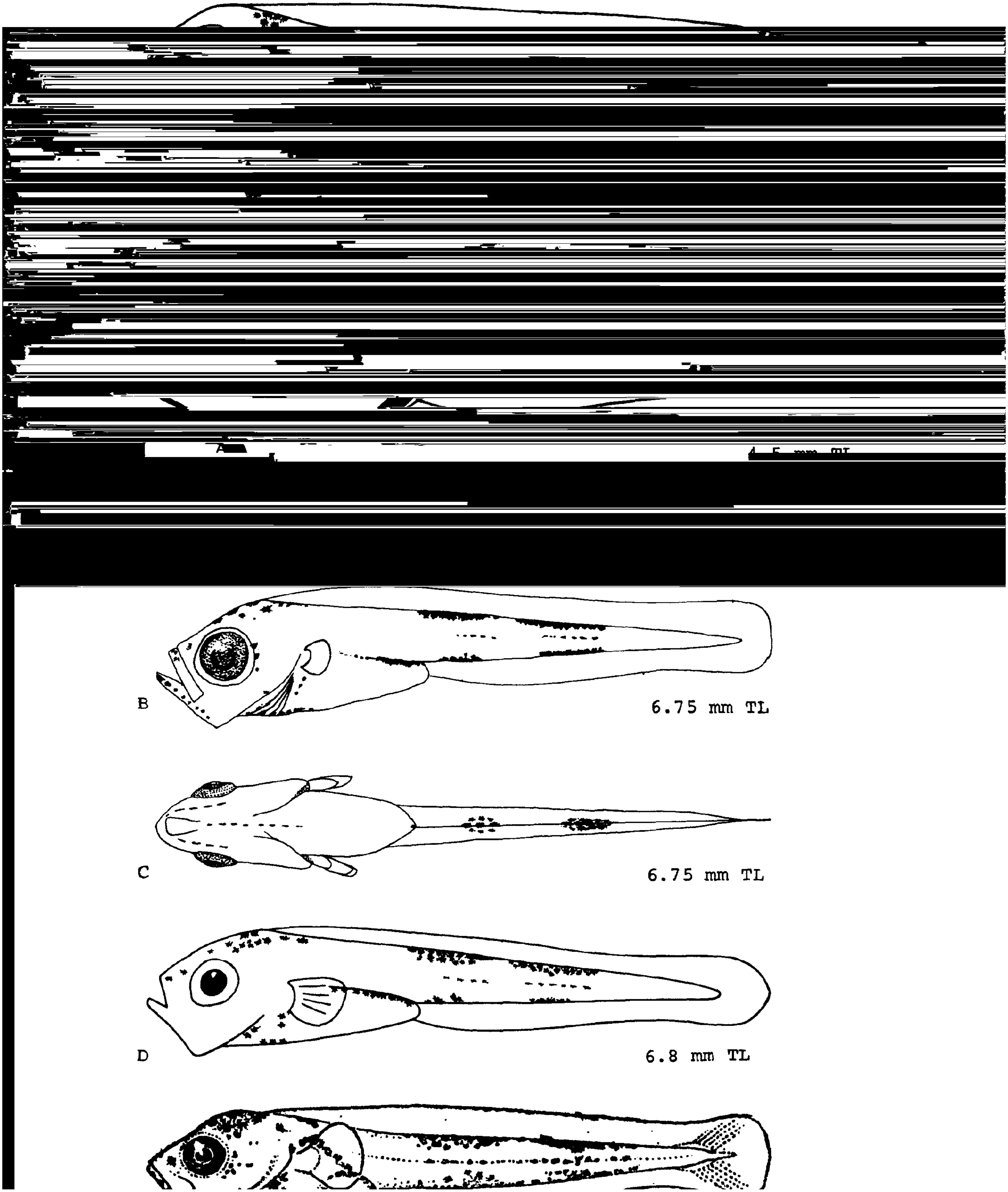
Hatching length, 3.2 [9,73] to 4.2 mm, average 4.0 mm.[11] Yolk absorbed at 3.5 [9] to ca. 5.3 mm.[80] Duration of stage, ca. 5 days (at 6.1 C) [6,60,72] to at least 14 days.[15] Mandible projected, mouth slightly open by 7th day or ca. 4.0 mm.[80] At time of hatching, origin of dorsal finfold about over pectoral fins.[59] Opening of anus lateral and at base of finfold.[11]

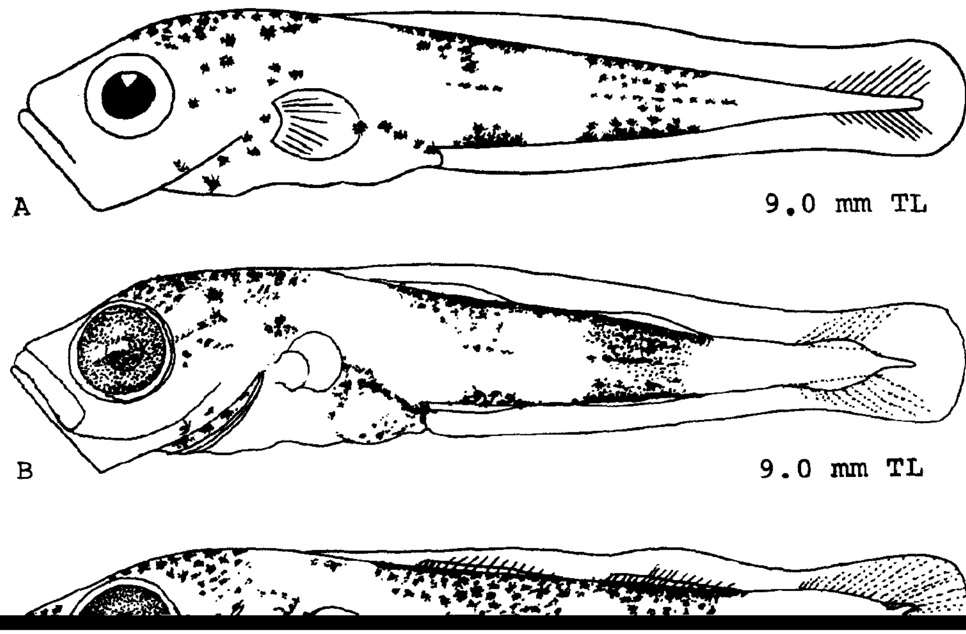
Pigmentation: At hatching, transparent; [21] pigment slight, scattered,[77,80] lacking on yolk sac,[78] and in eye.[59,77] At 3 days eye with minute black dots and silvery hue.[80] By



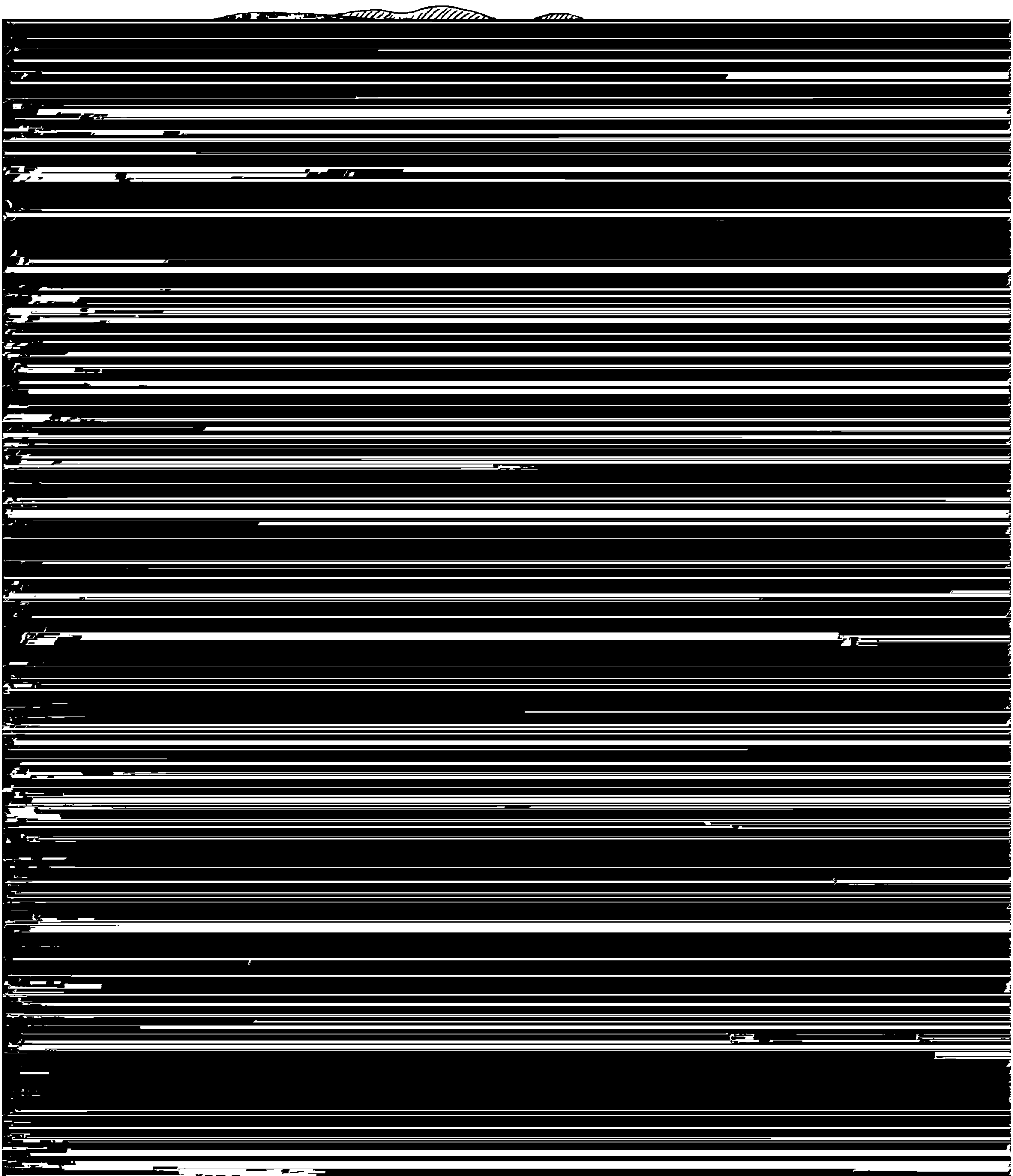
B 3.9 mm TL




B
6.75 mm TL
C
6.75 mm TL
D
6.8 mm TL



[redacted]



By 14th day yolk sac distinctly reticulated, ventral chromatophores more scattered.[15]

LARVAE

Size range described, 4.0 to 23.0 mm.[41,77]

Abdominal vertebrae, 23–25, mean 23.6.[11]

Head short, blunt (distinctly shorter than that of cod at 15.0 mm).[41] Development of unpaired fins first evident at 9.0 mm.[59] Incipient rays in D. 2 and D. 3, and in anal fin at 9.0–11.0 mm.[41,77] At 20.0 mm A. 1 considerably lower and clearly longer than A. 2[59] Caudal rays apparently not evident in some specimens until 6.75 mm; at 12.5 to 30.0 mm caudal fin somewhat concave.[6,41,57] Pelvics evident as low knobs at 12.5 mm; at 15.0 mm no longer knob-like and not quite 1/4 diameter of eye; at 20.0 mm pointed, less than 1/2 diameter of eye.[41] All unpaired fins separated by 20.0 mm.[59] Urostyle straight at 9.0 mm,[77] oblique at 11.0 mm.[41] Position of anus variously stated: At ca. 8.0 to 20.0 mm a little in front of D. 2; at 20.0 mm under posterior end of D. 1; at ca. 15.0 to 30.0 under posterior 3rd of D. 1[41,57]

Pigmentation: Living larvae with small yellow chromatophores on body.[83] At time of yolk absorption 2 dorsal and 2 ventral pigment bars; dorsal bars longer than ventral (opposite in cod); space between bars greater ventrally.[11]

At 4.0 mm as above; also a weak mediolateral streak (which fails to reach anus), stellate chromatophores on

black pigment along dorsal margin; abdomen with black pigment specks and tinted red from food.[15,80]

At 11.0 mm original posterior bars no longer evident; mediolateral streak distinct, usually broken; dorsal pigment much stronger than ventral.[41]

At 12.5 mm ventral pigment weak; anterior part of abdomen possibly with silvery color; yellow pigment increased, now extending back as far as black pigment extends and more abundant posteriorly than anteriorly, also developed on occiput; forward part of abdomen definitely with silvery sheen.[41,59,77]

At 15.0 mm mediolateral streak extended forward almost to beginning of D. 2 backward a little beyond limits of dorsal and ventral pigment; ventral pigment weaker than dorsal.[41]

At 20.0 mm black pigment between rays of D. 1 and D. 2; pigment on flanks denser and extended posteriorly; lateral light area now sparsely covered with chromatophores; dorsal pigment reaches anterior part of caudal fin, but end of tail still without pigment; mediolateral line continuous; preanal pigment sparse.[41,59,77]

At 23.0 mm pigment on all dorsal and anal fins.[41]

PREJUVENILES

Size range, 25.0 to 50.0 mm (based on time of descent to bottom).[28,59]

Specimens described, 25.0 to 33.0 mm.[20,59] At 25.0 to 30.0

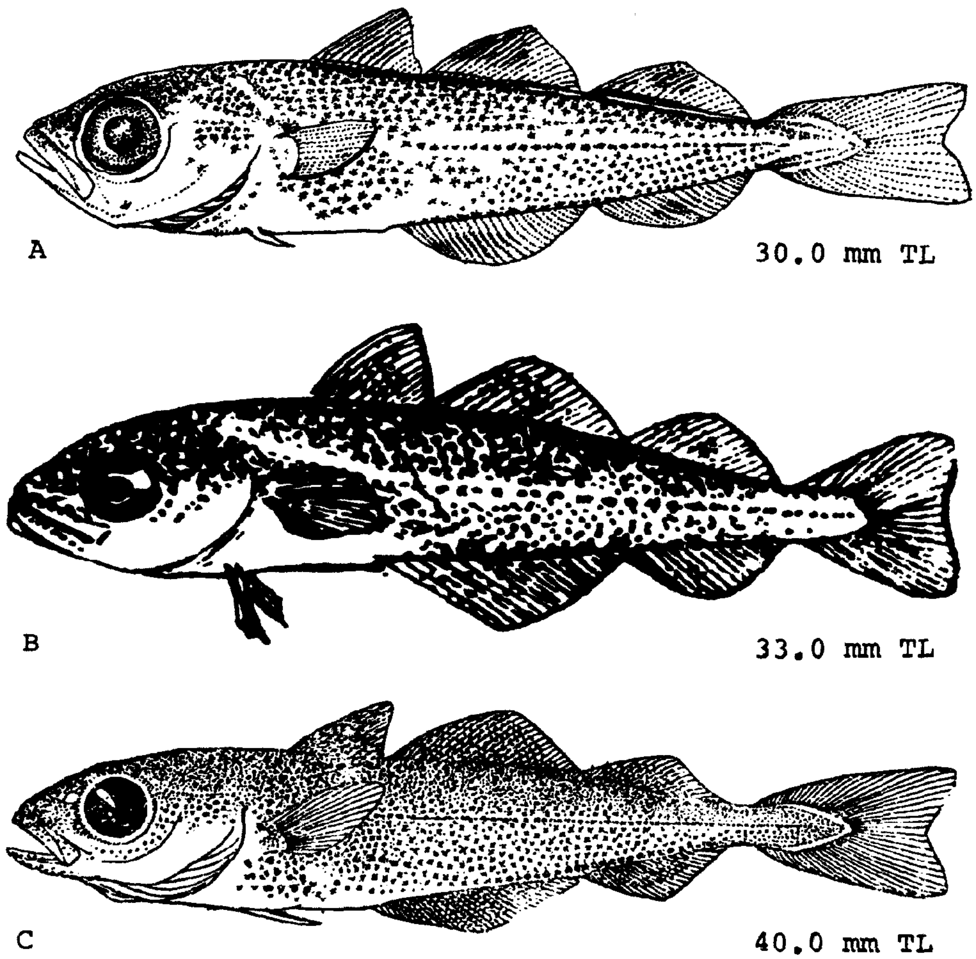


Fig. 187. *Pollachius virens*, Pollack. A. Juvenile, 30.0 mm TL, pectoral fin elongated. B. Juvenile, 33.0 mm TL. C. Juvenile, 40.0 mm TL. (*A, Schmidt, J., 1905: pl. 1, Joan Ellis, delineator. B, Ehrenbaum, E., 1909: fig. 89, after Heincke, F., 1909. C, Rass, T. S., 1949: fig. 24.*)

cept for preanal ventral wall; back dark; abdominal area silvery, unpaired fins, except caudal, well pigmented.[59]

JUVENILES

Minimum size, 50.0 mm.[28,59]

Juveniles apparently develop small, rudimentary chin barbels (but barbels, as a rule, absent in adult).[28,68]

Pigmentation: Specimens up to 60.0 mm (description includes some prejuveniles) with deep green hue; abundant black pigment on fins and body; dorsal and anal fins sometimes with yellow spots; pectorals sometimes with 2 broad arches of pigment.[15]

Young fish darker than larger ones and sometimes tinged with yellow on sides.[68]

At sizes below ca. 380 mm usually brownish green.[20]

AGE AND SIZE AT MATURITY

Minimum 3 years [12,68] (an implication of maturity at 2 years [6] is questioned, JDH). Generally males at 4 to 7 years, females at 5 to 7 years,[1] most spawn for first time at five years, majority at 6 years, all by 7 years.[12,37,39]

Mature by 340 to 700 mm [13,39,61,62,63] (a report of ripening at ca. 172 mm [6] is questioned, JDH). Various minimums: In Manx waters 340 mm; [13] off Europe ca. 457 mm; [68] in Newfoundland waters 540 mm; [36] in Bay of Fundy males 500 to 650 mm, females 550 to 700 mm; [1] in Icelandic waters 500 [19] to 700 mm.[39] Individuals in American waters probably mature at somewhat larger sizes than those in European waters.[68]

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Urophycis chuss (Walbaum), Red hake

ADULTS

D. 1, 9–11;[6,9,12] D. 2, 53–64; A. 45–56;[21,45] C. 30;[41] P. 16;[9] V. 2;[10] scales 95–117 (reports of 110–140 include *U. tenuis*),[21,45] scale rows above lateral line in vicinity of first dorsal, 9;[22] total vertebrae 45–50 (including hypural), precaudal vertebrae 14–17, mode 15,[21,45] caudal vertebrae 33;[41] gill rakers on lower branch first arch 12–13,[12] epibranchials of first arch 3,[21,45] but gill rakers also stated as 16–18.[9]

Proportions as times in TL: Depth 4.8[12] to 5.5;[6,10] head 4.25–4.5.[12] Proportions as percent HL: eye 24.9–28.4; interorbital space 16.7–17.1.[9]

Body somewhat elongate,[12] rounded in front of vent, somewhat compressed behind. Head more or less pointed,[10] noticeably broader than deep, depressed.[12] Upper jaw projecting[10] maxillary bone usually to rear edge of pupil;[12,21,32,45] a small barbel on lower jaw.[10] Teeth on jaws and vomer, those in upper jaw in 2 indefinite rows, those on lower jaw very irregular.[12] Third ray of first dorsal filamentous and much longer than in *Urophycis tenuis;*[32] caudal fin rounded.[12]

Pigmentation: Sides and back reddish, muddy, olive reddish, olive brown, or, rarely, almost black; sometimes mottled. Lower sides usually washed with yellow, sometimes marked with dusky spots. Belly white, grayish, or yellowish. Unpaired fins same as back, but anal pale at base. Pelvics pale pinkish or yellowish.[9,32]

Maximum length: Ca. 760 mm.[6]

DISTRIBUTION AND ECOLOGY

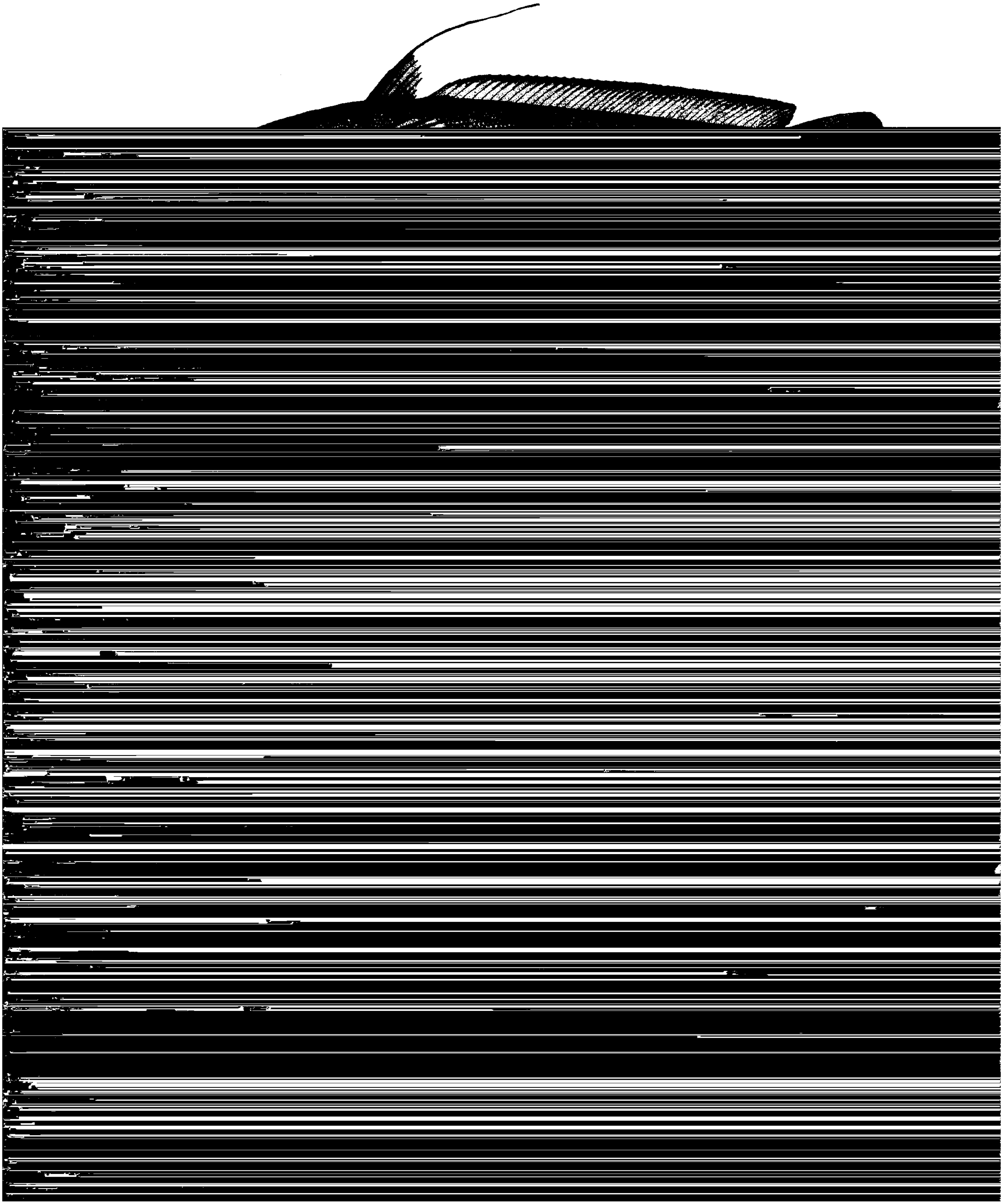
Range: Along continental shelf from Nova Scotia to Cape Hatteras. Records from Labrador, Grand Bank, the

known to enter harbors.[31] Tend to stay close to objects on the bottom (such as sea scallops, etc.).[37] Typically over soft mud or silt bottoms, less frequently over sand and shell, never over rock.[4,9,12,21,45] Minimum recorded depth, 35 m[9] (although reported from within a hundred feet of shore[12] and from the tide line). Estimates of greatest abundance vary from 110 to 130 m,[9] 182 m, and 457 m,[18] but these differences may reflect seasonal movements.[21,45]

Make definite inshore-offshore movements[5,12] which are apparently governed by temperature (avoiding temperatures below 5 C). In New England generally inshore in April and May and again in October.[5,11,12,21,29,45] Offshore to edge of continental shelf in winter.[21,45] In Block Island Sound in spring, summer, and fall; absent in winter.[16] In Sandy Hook, New Jersey, and Long Island, New York, inshore in spring and fall, offshore in summer and winter.[21,30,45] Inshore at Ocean City, Maryland, from October 1 to December 10.[23]

Larvae—putative larvae drift at surface, sometimes under floating eelgrass and rockweed.[32] Larvae with mean lengths of 3.2–9.4 mm inshore along coast of Maine June through November.[42]

Juveniles—initially at surface,[29] but primarily on bottom. Found in mantle cavity of scallops (*Placopecten megallanicus*) at lengths of 27 to 140 mm and remain in vicinity of scallop beds until 2nd year of life if temperature remains above 4 C;[1,4,21,45] also recorded as hiding under shells, sponges, or litter,[37] associated with jellyfish,[25] and, at ca. 60 to 150 mm, in eelgrass along shore;[29] a specimen ca. 225 mm long was found inside the egg case of a naticid gastropod (probably the moon snail, *Lunatia heros*).[34] Juveniles 11.5–38.5 mm long offshore near 180 m depth contour;[44] specimens 68–139 mm long recorded



During the following spring they migrate inshore with adults in April, and become mature by summer.[4,21,45] Young ca. 50 to 225 mm long in Chesapeake Bay in late fall and spring, leave for offshore waters by end of June.[12]

SPAWNING

Location: On continental shelf with concentration on southeastern Georges Bank and south of Long Island.[21,45] Spawning has been reported as far south as New Jersey, and a female with ripening ovaries was reported from Chesapeake Bay.[12,21,32,45]

Season: Principally in summer,[3,12,30] but apparently prolonged, based on distended ovaries in April, eggs in late September,[32] and newly hatched young in October.[6,21,45] In New England May to August; [7] in Georges Bank June

Incubation period:

At 15.6 C, 96 [38]–98 + hours.[35]
At 21.1 C, ca. 30 hours.[17]

YOLK-SAC LARVAE

Hatching length, 1.76 [7,17,20]–1.98 mm.[6] Largest specimen described 2.2 mm.[7] Duration of stage, ca. 22–38 hours (although remnant of oil globule is evident at 62 hours).[17]

At time of hatching yolk mass large and extending far forward under head; oil globule in posterior part of yolk sac. Dorsal finfold extended forward to head throughout stage. Pectoral bud evident in smallest specimen illustrated (ca. 1.9 mm), but otherwise not noticeable until length of 2.75 mm.[6] Anus located laterally and at base of finfold.[7] Sensory organs of lateral line evident as distinct but very delicate and perfectly transparent

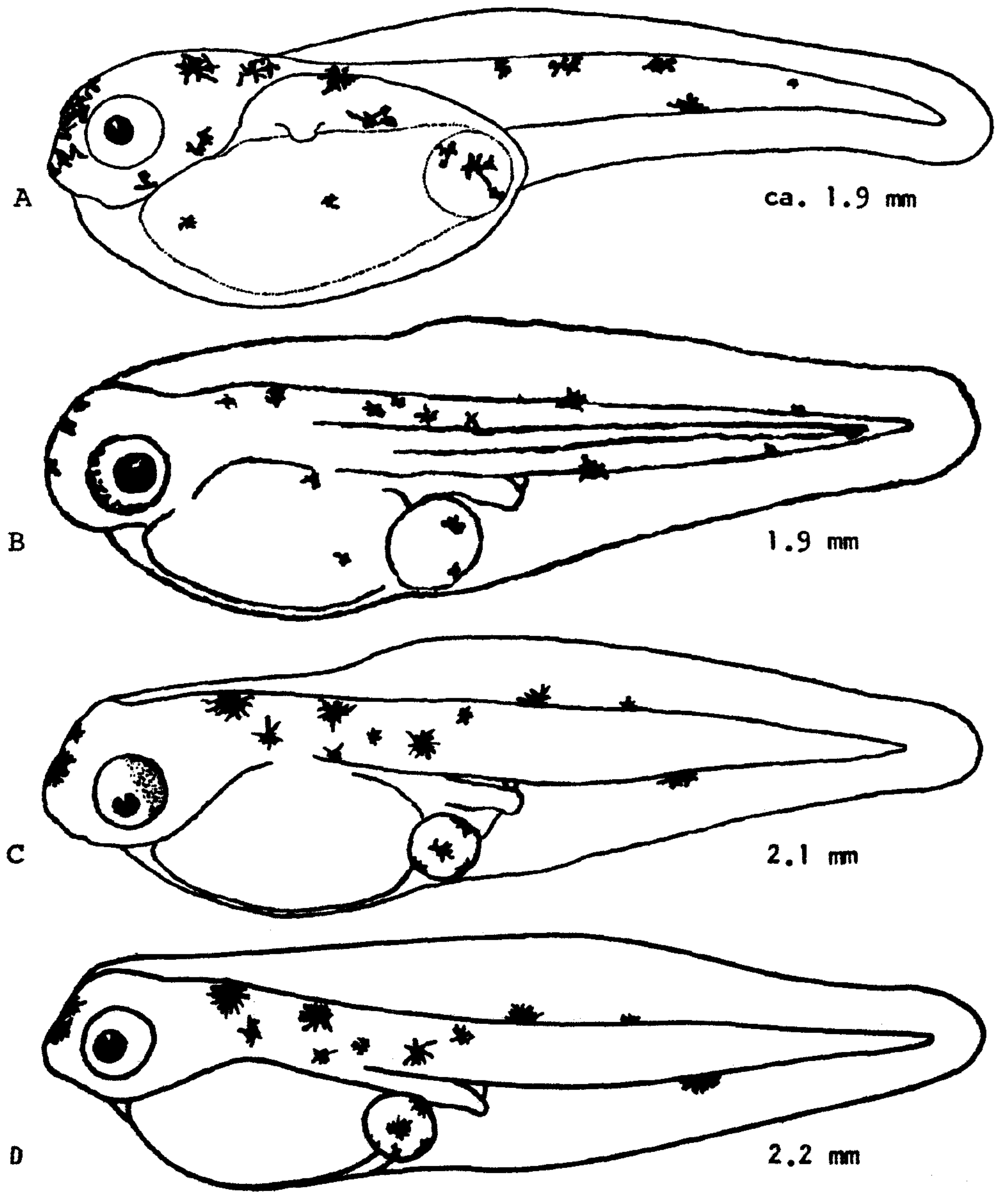


Fig. 189. *Urophycis chuss*, Red hake. A. Yolk-sac larva, newly hatched, ca. 1.9 mm. B. Yolk-sac larva, 1.9 mm. C. Yolk-sac larva, 2.1 mm, 3 hours old. D. Yolk-sac larva, 2.2 mm, yolk sac noticeably reduced. (*A, Hildebrand, S. F., and L. E. Cable, 1938: fig. 127. B, Miller, D., 1958: 35. C, Miller, D., and R. R. Marak, 1959: fig. 1. D, Colton, J. B., and R. R. Marak, 1969: 20.*)

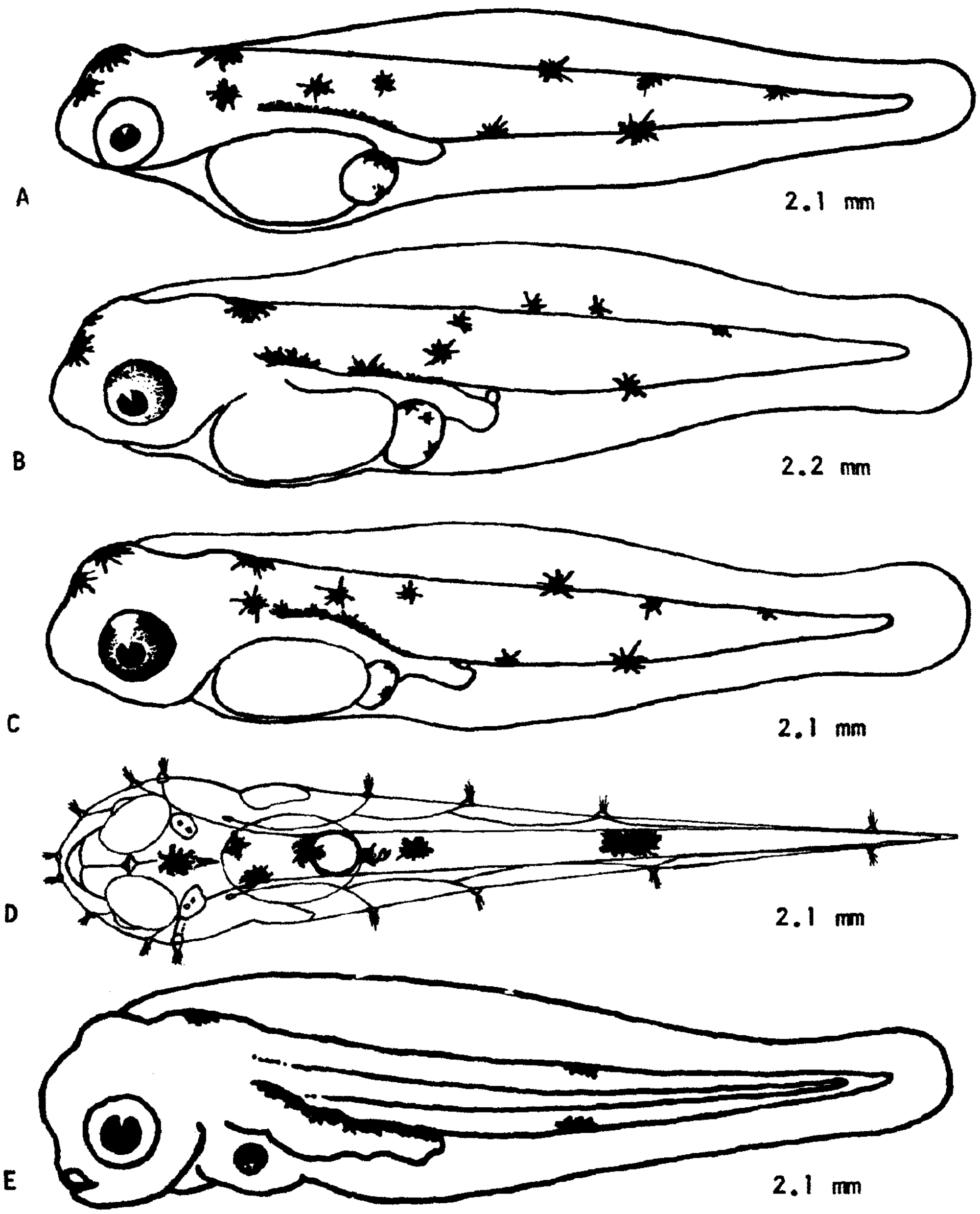


Fig. 190. *Urophycis chuss,* Red hake. A. Yolk-sac larva, 2.1 mm, pigment developed over gut. B. Yolk-sac larva, 2.2 mm. C. Yolk-sac larva, 2.1 mm. D. Yolk-sac larva, 2.1 mm, dorsal view to show development of lateral line organs. E. Yolk-sac larva, 2.1 mm, pigment on body noticeably decreased. (*A, Colton, J. B., and R. R. Marak, 1969: 20. B, C, Miller, D., and R. R. Marak, 1959: figs. 2–3. D, Redrawn from Agassiz, A., and C. O. Whitman, 1885: pl. 12, Frances P. Younger, delineator. E, Miller, D., 1958: 36.*)

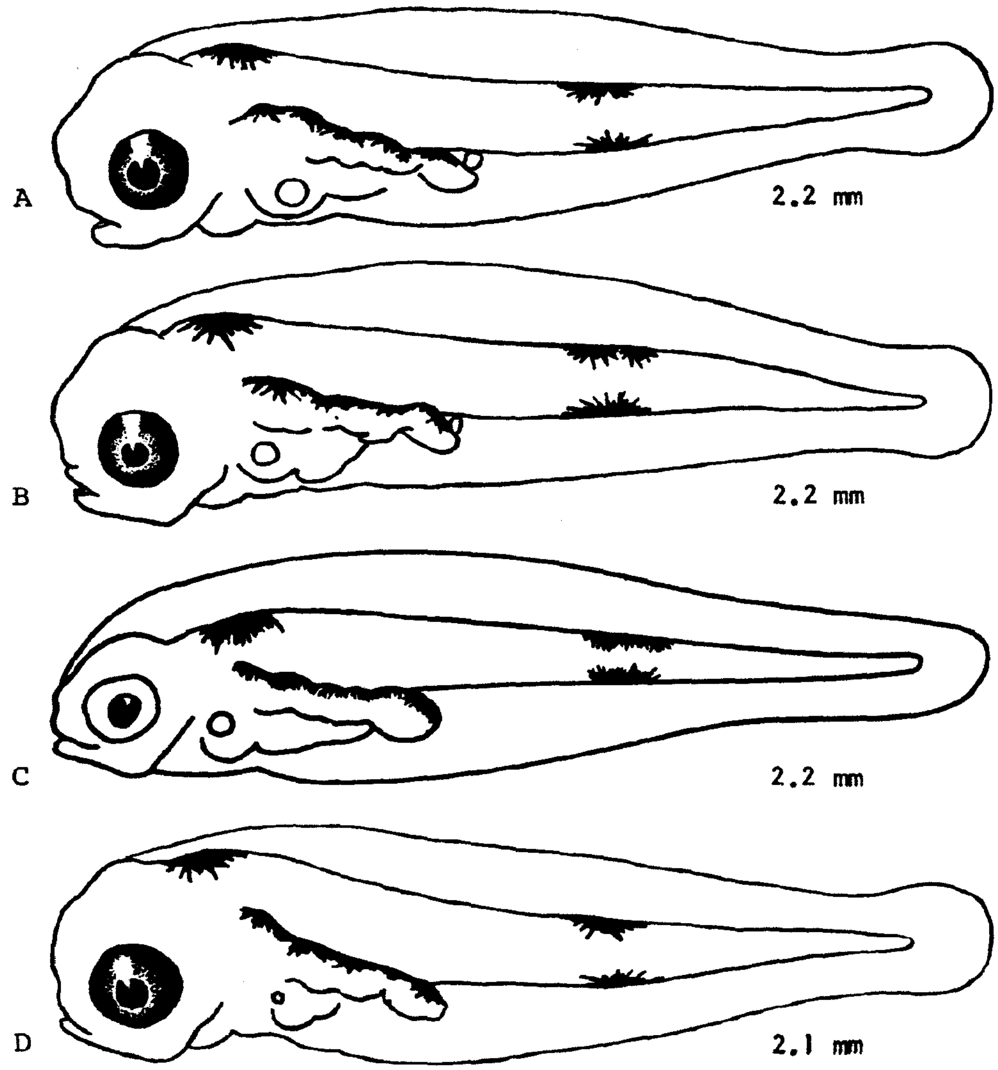
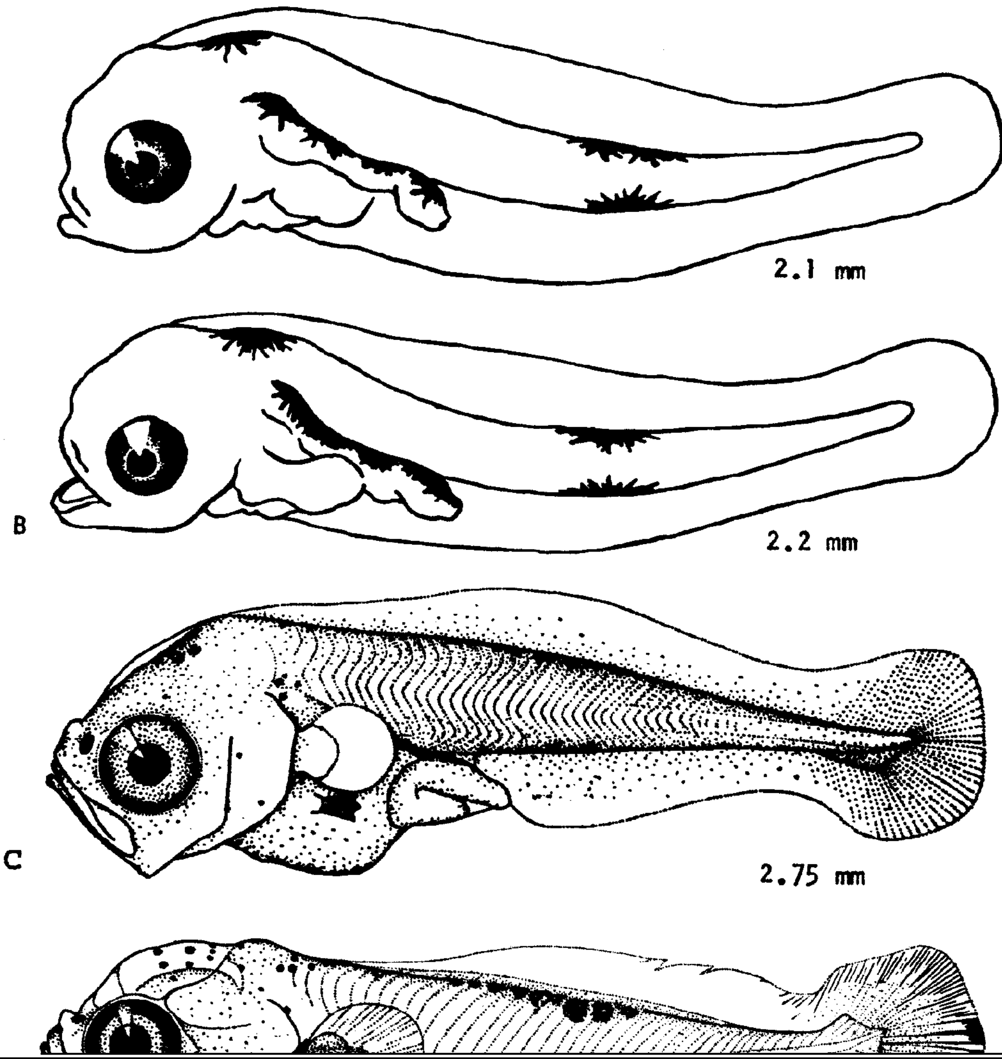
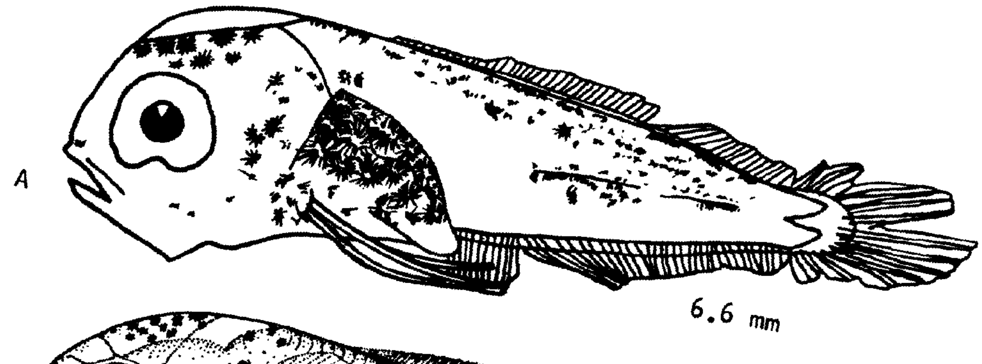


Fig. 191. *Urophycis chuss*, Red hake. A. Yolk-sac larva, 2.2 mm. B. Yolk-sac larva, 2.2 mm. C. Yolk-sac larva, 2.2 mm. D. Yolk-sac larva, 2.1 mm, oil globule greatly reduced. (*A, B, Miller, D., and R. R. Marak, 1959: figs. 4–5. C, Colton, J. B., and R. R. Marak, 1969: 20. D, Miller, D., and R. R. Marak, 1959: fig. 6.*)


2.1 mm
B
2.2 mm
C
2.75 mm



[redacted]

profound changes in pigmentation. At 2.2 mm (38 hours) a single large chromatophore on back of head, peritoneum over gut heavily pigmented, and one dorsal and one ventral pigment spot about halfway down tail.[17] At 5.0 mm distal membrane of pelvics black.[6] At ca. 6.0 mm pattern evident, but pigment more scattered.[7,20] At 9–11 mm melanophores on head and back and, sometimes, on cheek, opercle, and first dorsal.[6]

PREJUVENILES

Size range described, 15[6]–49 mm.[21,45]

Anterior nasal aperture with distinct fleshy collar at 24.5 mm.[16] Chin barbel evident at ca. 15 mm.[6] Body laterally compressed at 30–40 mm.[21,45] Scales first evident at 25 mm, fully formed at 35–50 mm.[6] At 24.5 mm dorsal origin posterior to pectoral origin when viewed from above.[16] Caudal variable, round, straight, or slightly concave at ca. 15 mm.[6] Pelvics well beyond anus at 24.5 mm.[16]

Pigmentation: At ca. 15 mm dark pigment generally increased. Black pigment at tip of pelvics lost through size range of ca. 25–40 mm.[6] At 30–40 mm blue above, silvery on sides and belly;[21,45] "fry" also described as greenish on back, silvery on sides.[12]

JUVENILES

Body terete within 12 hours after becoming demersal; at 59–66 mm pelvics and head longer, body less deep

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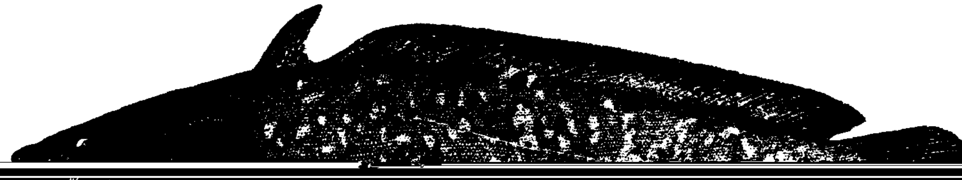
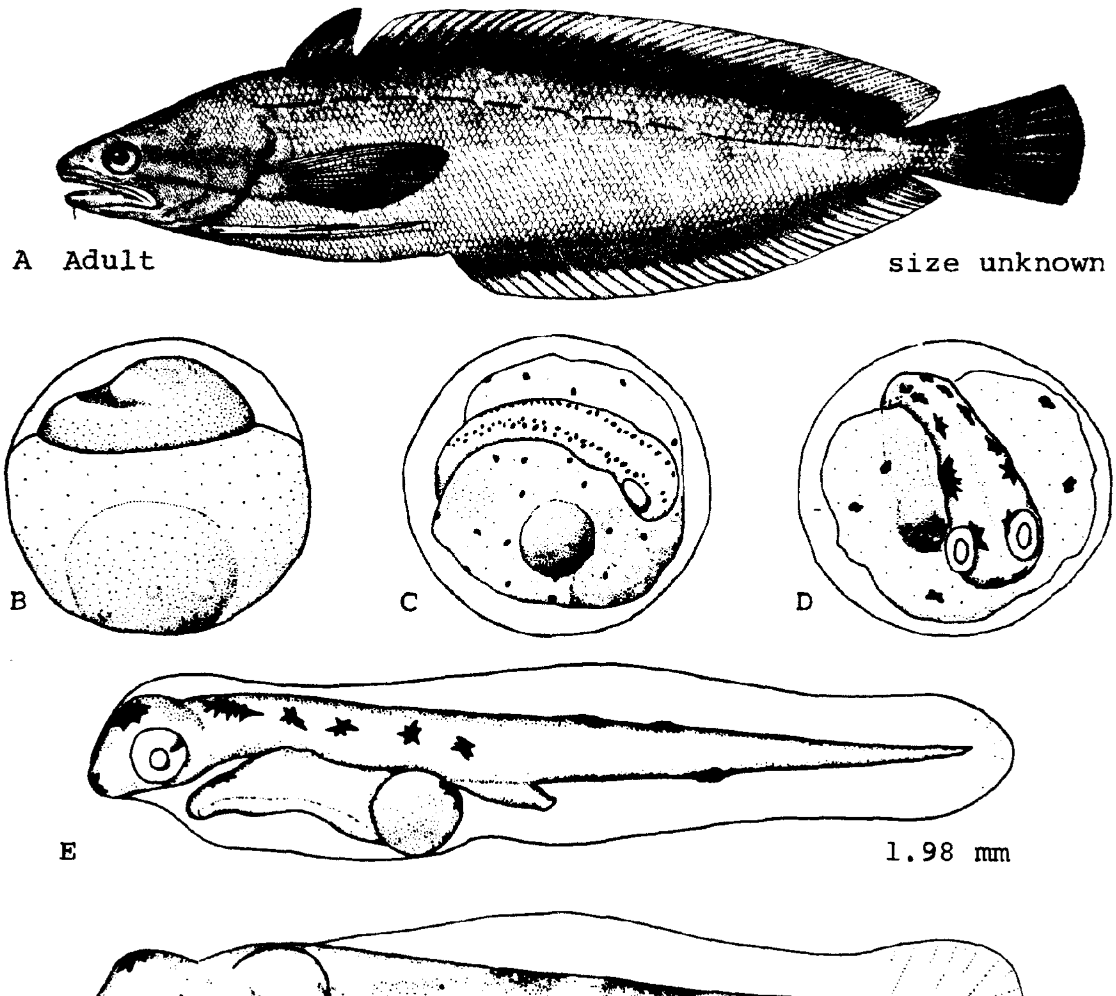


Urophycis regius (Walbaum), Spotted hake

ADULTS

D. 1, 7–9, mostly 8; D. 2, 43–51; A. 41–45 (JAM) or 50;[31] C. 30–32; P. 16;[7] V. 2;[8] scales 83 (JAM)–97;[6,7,11] total

phycis floridanus was collected 10 to 21 km off Beaufort, North Carolina. Depth of capture not reported.[6] Specimens as small as 8.0 mm near the 183 m depth contour.[33]


A Adult
size unknown
B
C
D
E
1.98 mm

0.73) when recently fertilized. Oil globules vary during development: at 12 hours a single large oval globule, diameter 0.34–0.45 mm (mean 0.40 mm); at 18 hours a cluster of small accessory oil globules; at 24 hours size of large oil globule 0.14–0.22 mm (mean 0.18 mm), diameter of cluster of accessory globules ca. 0.40 mm. Perivitelline space ca. 0.05 mm wide directly above blastodisc at 18 hours, decreasing in thickness between yolk and egg capsule toward vegetal pole; at 24 hours, sometimes up to 0.10 mm wide.[26]

EGG DEVELOPMENT

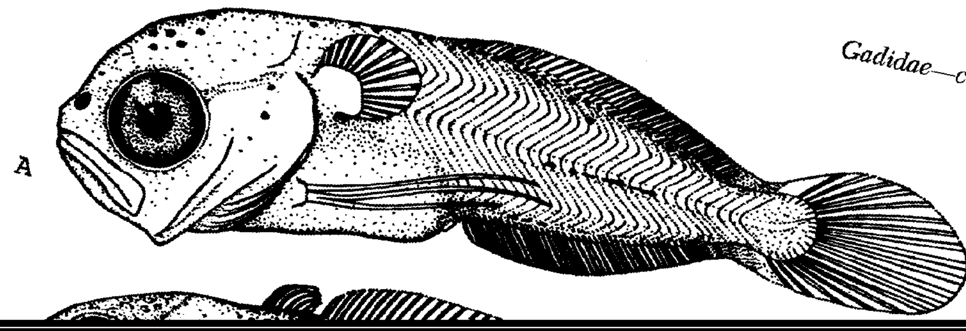
At 22–23 C:

After 12 hours—blastodisc well-developed and opposite oil globule.

After 18 hours, all eggs with distinct oil globule

Jaws "poorly developed" at 2.05 mm (36 hours). Oil globule located posteriorly during at least first 18 hours, still present, but reduced, at 36 hours. Pectoral fins first evident between 18 and 36 hours (2.03–2.05 mm); incipient caudal rays at 36 hours; dorsal finfold forward to tip of head during first 18 hours; anal opening lateral and at base of ventral finfold.[36]

Pigmentation: A prominent melanophore on anterior tip of head throughout stage. In recently hatched specimens postorbital melanophores now shifted in position and located slightly above eyes; 5–6 pairs of melanophores dorsolaterally from nape to vent, 1 or 2 on dorsal surface posterior to vent, and a single large melanophore on ventral surface slightly posterior to them. At ca. 12 hours melanophores above eyes migrate to crown of head and form a single large pigment spot. At ca. 18 hours pigment developed along dorsal surface of alimentary canal. At 36 hours (2.05 mm) diffuse pigment over much of


A

at 35.0–50.0 mm maxillary broad posteriorly; barbel scarcely half as long as eye diameter by end of stage.[6]

Proportions as times in TL (at ca. 25.0 mm), depth 4.0–4.6, head 3.3–4.0. Proportions as times in head, snout ca. 4.0–4.4, eye 3.3–3.6.[6]

Pectoral origin beyond anal origin at 35–50 mm. Scales present at 25 mm.[6]

Pigmentation: At 35–50 mm bright green to bluish above; a black area surrounded by white on distal end of first dorsal.[6]

JUVENILES

Minimum size described, 60.0 mm.

At ca. 100 mm eye narrower than interorbital distance, 5.1–6.5 times in HL.[6]

Pigmentation: At 60 mm four black dots in a vertical row sometimes present behind eye, also a spot over eye, another posterior to nostril, and 3 on opercle; dark lateral stripe containing roundish pale spots sometimes present, although often not evident until much larger size.[6]

At ca. 94 mm a series of 15 prominent light spots along developing lateral line from region above pectoral fin to caudal base; several dark lines on opercle radiating from eye.[29]

At 153 mm brownish above, white below; white spots along lateral line connected by thin black line; first dorsal edged with white and with a prominent jet black spot; 2nd dorsal uniformly dark; anal white or pinkish at base, bluish at center, edged with black; pelvics white; pectorals pale dusky, edged with light yellow.[11]

At ca. 150 mm body gray, mottled with brown; belly glistening white; 14–16 light lateral line spots; top of head with pale diamond-shaped mark; a dark band across nape and another behind each eye; first dorsal jet black, almost entirely surrounded by narrow pure white margin; 2nd dorsal gray with round dark spots; caudal dusky gray with dark edge; pectoral dusky with white margin; pelvics glistening white.[23]

AGE AND SIZE AT MATURITY

Females 310 mm, males 210 mm.[26]

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Urophycis tenuis (Mitchill), White hake

ADULTS

D.$_1$ 9–10;[7,22] D.$_2$ 50[14,26]–59;[7] A. variously stated, 41–52[14,26] and 53–57 (based on juveniles 84–115 mm long);[24] P. 16;[7] scales 119–148;[14,26] scale rows between lateral line and region of first dorsal, ca. 12;[16] total vertebral counts variously stated, 47–50 (excluding hypural),[14,26] also 56–57[24] (but probably in error, JAM); precaudal vertebrae 13–17;[14,26] caudal 42;[24] gill rakers 15–16, on epibranchial of first arch, 2.[7,21]

Proportions as times in TL: Depth 5.5.[22] As percent head length: eye 19.0–24.1, interorbital distance 18.3–18.6.[7]

Body rounded in front of anus, laterally compressed beyond; upper jaw projected beyond lower; gape extended to below eye; a small barbel on chin. First dorsal fin much longer than second, triangular, and with 3rd ray projected as a filament; pelvics in front of pectorals and consisting of a single elongate two-branched ray.[22]

Pigmentation: Variable. Brown, purplish brown, reddish brown, or slate above; sides sometimes bronzy; belly dirty or yellowish, with or without numerous small black dots; dorsal fin same color as back; anal fin same color as belly; pelvics with yellowish tinge; all fins with black edges.[7,22]

Maximum length: Ca. 1220 mm.[3]

Abundant at Woods Hole in October and November; absent in Block Island Sound in winter;[14,26] apparently inshore April to November in Rhode Island;[19] inshore at Orient, Long Island in spring.[14,26]

Larvae—pelagic;[1] putative larvae 17–22 mm long at surface off Long Island; also shallow enough to be washed ashore.[5] Apparently dispersed by current: Thus most larvae of New England population probably dispersed from Scotian shelf.[14,26]

Juveniles—young of unspecified size (but presumably juveniles) under floating or attached vegetation, and sometimes associated with jellyfish.[14,26] (Reports of young in shells of *Pecten tenuicostatus*[19] in error, JAM.) When inshore, demersal, but occasionally foraging to mid- and upper layers in shallow water environment.[14,26] Prejuveniles ca. 25 mm and longer sometimes associated with pollock in spring, often at surface under gulf weed and eelgrass;[8] specimens specifically within the size range of 13–71 mm recorded at surface.[6,12,21] Juveniles ca. 75–100 mm long recorded inshore in water ca. 1 meter deep, sometimes lying on sides in sand with head projecting;[4] specimens 150–320 mm long in harbors,[5] estuaries,[16] mouths of rivers,[14,26] and tributary inlets of bays,[2] as well as offshore;[16] at 90–500 mm frequently recorded in water deeper than 180 m. Temperature range, 2–15 C, with some seasonal variation; temperature of greatest abundance 4–10 C.[14,26] A tran-

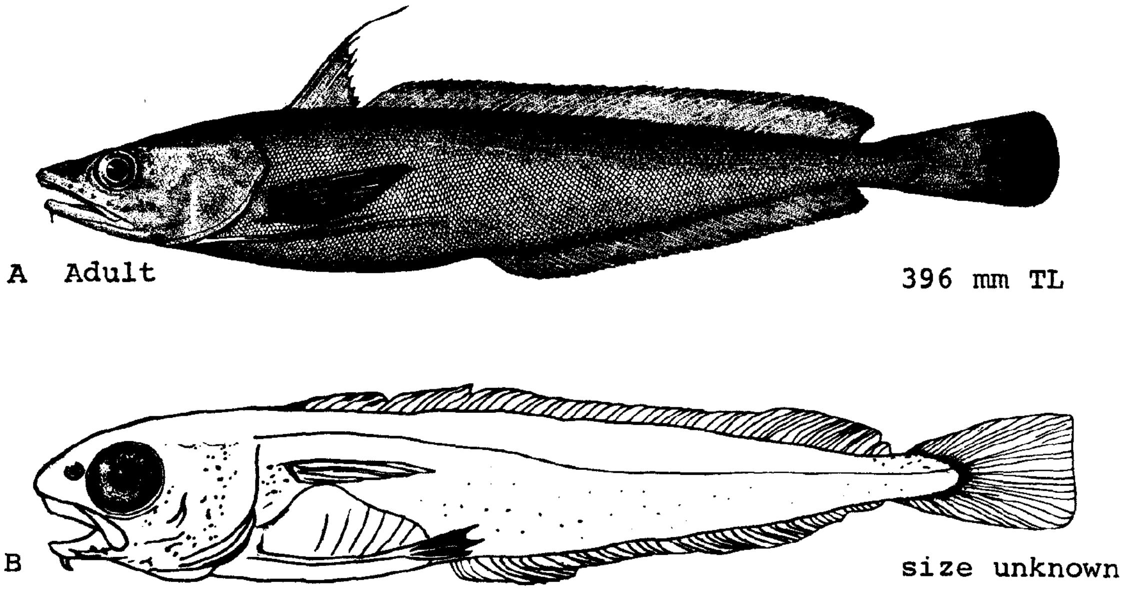

Fig. 197. *Urophycis tenuis*, White hake. A. Adult, 396 mm TL. B. Larva, size unknown, barbel developed, first dorsal incomplete. (*A, Jordan, D. S., and B. W. Evermann, 1896–1900: fig. 901. B, Original drawing, artist unknown, Virginia Institute of Marine Science.*)

Lawrence spawning aggregations in June.[14,26]

Depth: A female with "large row" at 160 m.[22]

Fecundity: No information.

EGGS

Pelagic.[1,26]

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

PREJUVENILES

Size range described, 23.5 [11]–80 m (based on maximum size at time of descent to bottom).[14,26]

At 23.5–27.0 mm a flap of skin extended from anterior to posterior nasal aperture, origin of dorsal at level of insertion of pectorals, pelvics not extended to anus [11] (but apparently none of these characters specifically diagnostic of young of this species). At 59–66 mm pelvics shorter, body deeper, and head relatively larger than in similar-sized specimens of *Urophycis chuss*.[14,26]

Pigmentation: Back dark, otherwise bright silvery, iris silvery with decidedly blue tinge,[5] interradial membrane of pelvics black.[14,26] Remain silvery to 67–76 mm TL.[5]

JUVENILES

Minimum size described, ca. 200 mm.

Pigmentation: At ca. 200 mm brown [6] to purplish gray (JAM) above; sides brassy tinged with purple; belly and pelvics contrastingly white; iris dark brown; 2nd dorsal and anal dark gray narrowly edged with dusky; caudal a little browner; 1st dorsal black, its filament pale; a dark streak bordered on each side by pinkish white extending below eye from center of upper jaw.[5]

AGE AND SIZE AT MATURITY

Mature at 4 years; [14] mature by 500 mm; [1] males by 400 mm, females 480 mm.[14,26]

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Merluccius albidus
Merluccius bilinearis

merlucciid hakes
Merlucciidae

FAMILY MERLUCCIIDAE

Merlucciid hakes, of which there are two subfamilies (Macruraninae and Merlucciinae), five genera, and about 13 species, occur in the Atlantic and eastern Pacific oceans as well as in Tasmania and New Zealand. These fishes have one or two dorsal fins and one anal fin; the first complete dorsal ray is a flexible spine. Teeth are present on the vomer; the mouth is large and terminal; and the jaws are equipped with long teeth, some of which, in the subfamily Macruraninae, may be fang-like. Chin barbels and pyloric caecae are lacking. Members of the subfamily Merlucciinae, to which both regional merlucciids belong, lack fang-like teeth. The caudal fin is truncate and not continuous with the dorsal and anal fins; the pelvic fins are well in advance of the pectoral fins.

The merlucciid fishes spawn in marine waters, and at least some of them undertake definite spawning migrations. Eggs of both regional species, *M. albidus* and *M. bilinearis*, have been illustrated. These species produce relatively small pelagic eggs (diameter 0.7–1.11 mm) with a conspicuous single oil globule. As in the gadids, the anal opening of larvae of the merlucciid hakes is at the side rather than at the edge of the finfold. Development of the pelvic fins is precocious, although not as strikingly so as in certain members of the gadid subfamily Lotinae. In the Lotinae only three pelvic rays develop, while in the Merlucciinae there are typically more than three pelvic rays. Larvae of the regional merlucciid species can be distinguished from larvae of most Mid-Atlantic Bight gadids by their high preanal myomere counts (25–28). They are further distinguishable by the presence of two conspicuous, widely separated pigment patches on the tail posterior to the anus.

For more detailed descriptions and methods of distinguishing eggs and larvae of merlucciid hakes from those of gadids, see the tables and keys to identification of eggs and larvae of gadoid fishes in the introduction to Gadidae.

Merluccius albidus (Mitchill), Offshore hake

ADULTS

D.$_1$ 10–13; D.$_2$ 35–41; A. 35–42; P. 12–17,[9] mode 15;[1,2,9] V. 7;[1,2] C. 34;[7] scales 129–148; gill rakers 1–3 + 8–9,[2,3] total 8–12; total vertebrae 50–56,[9] precaudal vertebrae 25, caudal vertebrae 26–27.[8]

Proportions as percent SL: Head 26.4–32.9; eye 4.6–8.4;[9] 1st dorsal base 9.1–12.3;[1] pectoral length 13.7–21.7;[9] pelvic length 12.1–17.6. Proportions as percent HL: eye 17.7–21.0, snout 28.2–36.3.[1] Eye as thousandths of SL (at 323–626 mm SL), 48–60.[2]

Cheek, preopercle, and interopercle almost wholly scaled; lateral aspect of snout naked or with lengthwise stripe of scales.[2] Base of tongue with teeth. Lower jaw extended beyond upper jaw. Barbels absent.[7]

Pigmentation: Dorsum dusky blackish blue (JAM) or brown with brassy hue; sides and belly white or silvery; iris yellow; pupil black;[7] peritoneum uniform dark brown or black in larger specimens, stippled with dots of darker in younger specimens.[2]

Maximum length: 691 mm SL.[2]

DISTRIBUTION AND ECOLOGY

Range: North to southeastern slope of Georges Bank (lat. 40° 46′, long. 66° 48′ W)[3] south to off Surinam.[9]

Area distribution: Recorded at 91–100 m off Delaware.[1]

Habitat and movements: Adults—probably on or close to bottom. Evidence of diel vertical migrations (JAM). Depth 91[1]–1170 m[2] and deeper in Caribbean (JAM).

Larvae—no information.

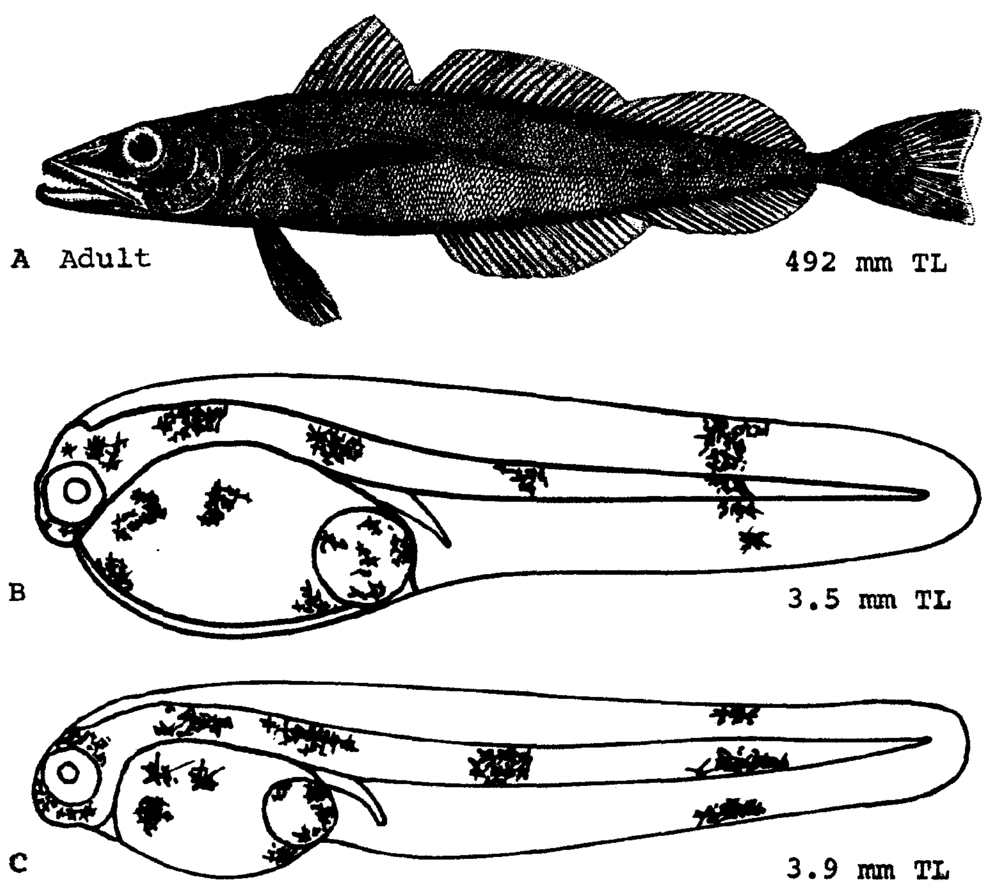

Fig. 198. *Merluccius albidus*, Offshore hake. A. Adult, 492 mm. B. Yolk-sac larva, just hatched, 3.5 mm. C. Yolk-sac larva, 3.9 mm. (*A, Ginsburg, I., 1954: fig. 1. B-C, Marak, R. R., 1967: figs. 1, 2.*)

Juveniles—specimens 33–66 mm at 106–122 m off Long Island.[1,4]

SPAWNING

Location: Ripe or near ripe females from Martha's Vineyard to Virginia.[1,4]

Season: April 26[4] to July 7.[1]

EGGS

Pelagic; spherical; transparent; diameter 0.99–1.18 mm, mean 1.10 mm. Oil globule single, diameter 0.29–0.36 mm, mean 0.32 mm. Perivitelline space narrow.[4]

EGG DEVELOPMENT

Eggs and developing embryos remain colorless until after tail-free stage at which time small stellate melanophores appear on body, yolk mass, and oil globule. Melanophores coalesce into patches as embryo develops.[4]

Incubation: At 8.9–10.6 C, 6–8 days.[4]

YOLK-SAC LARVAE

Hatching length: 3.05–3.75 mm, mean 3.54 mm.[4,6]

Oil globule in posterior part of yolk sac; anus opened laterally near middle of ventral finfold a short distance beyond yolk throughout size range described.[4]

Pigmentation: At hatching a group of melanophores in jaw region and on posterior part of head. Body with four distinct concentrations of pigment: dorsal to yolk sac, over vent, at midpoint of trunk, and 2/3 distance to end of tail. Posteriormost concentration extended onto dorsal and ventral finfolds. Large melanophores also present on anterior part of yolk mass and scattered on oil globule. Pigment remains about the same during first 84 hours of development.[4,6]

LARVAE

No information.

JUVENILES

Depth at origin of 1st dorsal as thousandths of SL at 75–91 mm, 175–180. Eye as thousandths of SL at 75–91 mm, 78–84.[2]

Caudal possibly rounded at 115 mm, generally truncate at ca. 125 mm SL, emarginated at ca. 240 mm SL (although sometimes remaining truncate to at least ca. 295 mm SL).[2]

AGE AND SIZE AT MATURITY

No information.

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1. Bigelow, H. B., and W. C. Schroeder, 1955:207–8, 211.
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3. Leim, A. H., and W. B. Scott, 1966:205.
4. Marak, R. R., 1967:227–8.
5. Briggs, J. C., 1958:269.
6. Colton, J. B., Jr., and R. R. Marak, 1969:17.
7. Mitchill, S. L., 1818:409–10.
8. Miller, G. L., and S. C. Jorgenson, 1973:306.
9. Karnella, C., 1973:84–90.

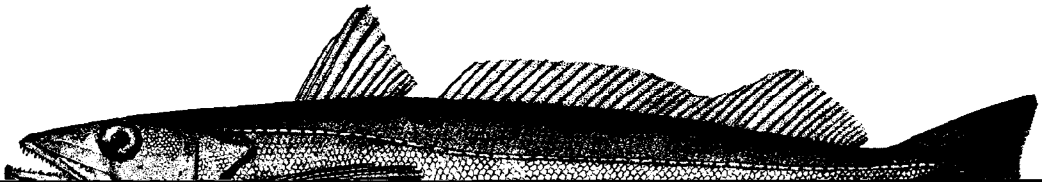
Merluccius bilinearis (Mitchill), Silver hake

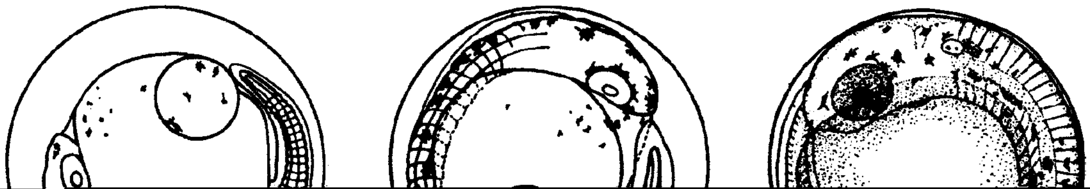
ADULTS

D. $_1$ 11–14; D. $_2$ 36–42; A. 37–42;[4,9,13,32] C. 32–36;[40] P. 13–17, mode 15;[4,9] V. 7;[14,40] scales 100[9,25]–130[4,10] (but counts vary widely, thus 100–110[9,25] and 112–130[4]); vertebrae 54–56 (but averages stated as 53.90–54.02),[30,32] precaudal vertebrae 27–28, caudal vertebrae 26–27;[48] gill rakers on first arch 2–6[4] + 10[9]–17, total 15–22;[4] branchiostegals 15–20.[32]

found in midwater (sometimes as far out as outer edge of the continental slope)[25] as well as near surface.[9] Known to become stranded on beaches, particularly when pursuing food at night.[2,10,14,26] Usually over sandy, pebbly,[2] or gravelly bottom,[9] seldom around rocks.[14] Sometimes in water not over 50 mm deep[21] at upper tide line;[14] out to over 914 m;[10] at 183 to 549 m in summer.[34] Reported from 3.3–17.8 C.[14]

Make inshore-offshore and, apparently, north-south move-





Usually in water less than 91 m deep, but in some areas such as southern New England and off Nova Scotia over much deeper water.[38,40]

Ovarian eggs: Three groups of eggs develop in the ovary simultaneously.[40]

Ovulated eggs: Transparent, nucleus shifted toward micropyle.[40]

Fertilized eggs: Spherical; highly transparent; diameter 0.70–1.11, stated averages 0.85,[40] 0.91.[7] Egg membrane described as smooth[40] and thin and horny.[8,16] Yolk light yellow, homogeneous, semitransparent, diameter 0.60–0.90.[40] A single, large,[2] relatively yellowish or brownish oil globule,[7,8,14,24] diameter 0.15–0.43 mm,[15] mean 0.26.[7,35] Perivitelline space 0.09–0.12 mm.[40]

EGG DEVELOPMENT

Development at unspecified temperature:

Incubation period: At ca. 20[40] to 22 C, ca. 48 hours;[2,11] normally develop at 12.2–15.6 C[13] or, possibly at 9–22 C[40] although development is apparently not normal at less than 10.0 C or above 18.3–21.1 C.[14] Eggs are killed by a change in temperature of over 20 C in less than 24 hours.[37]

YOLK-SAC LARVAE

Size at hatching 2.64–3.52 mm, mean 3.02 mm.[7,24] Maximum length reported, 4.42 mm.[40]

Body relatively slender, head slightly deflected over anterior end of yolk sac.[2,8] Oil globule evident to at least 3.3 mm.[7] At 4.42 mm jaw apparatus rudimentary.[40] At hatching depth of dorsal and ventral finfolds greater than body depth posterior to vent; conspicuously more slender by end of stage.[7,8] Incipient caudal rays evident at 3.3 mm[7] (although apparently lacking in a specimen 4.42 mm long). Rudiments of epurals and hypurals evident as enlargements in caudal portion of trunk at 4.42

A
B
C
D

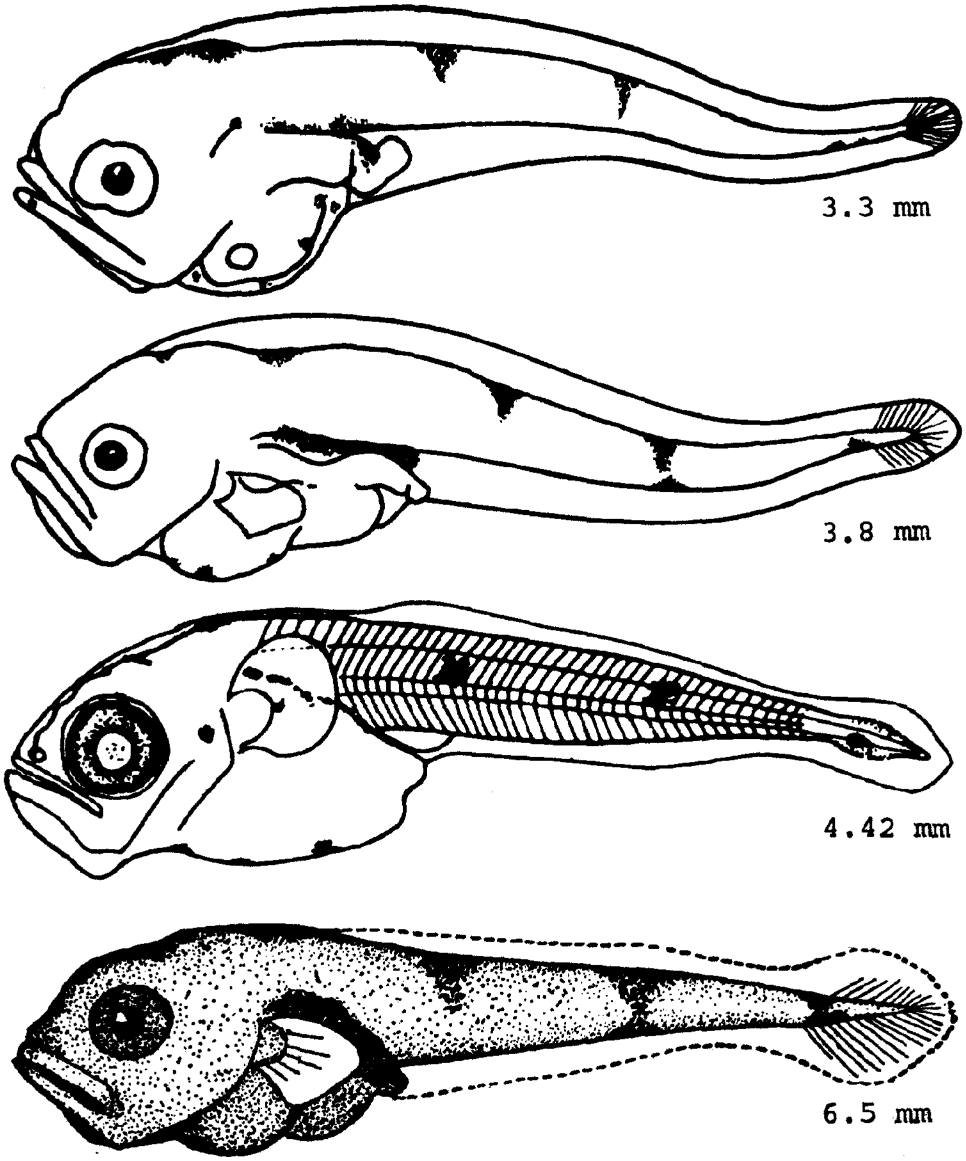
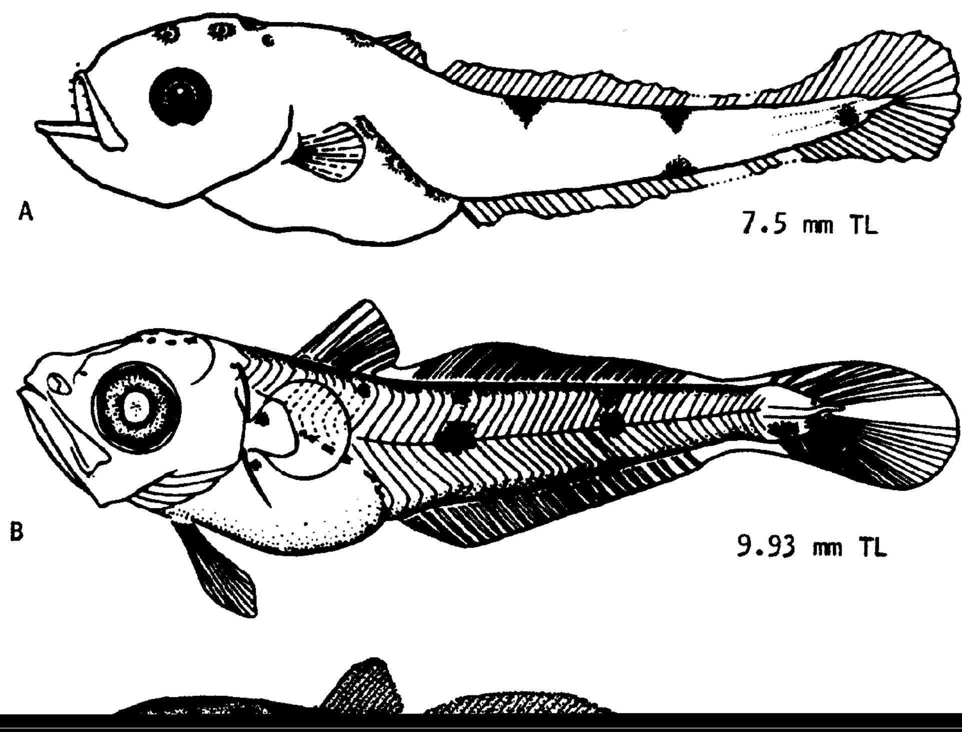


Fig. 201. *Merluccius bilinearis*, Silver hake. A. Yolk-sac larva, 3.3 mm, incipient caudal rays formed. B. Yolk-sac larva, 3.8 mm, oil globule no longer evident. C. Yolk-sac larva, 4.42 mm. Note atypical pattern, lack of caudal rays, and advanced development of pectoral fin. D. Larva, 6.5 mm. (*A, B, Miller, D., 1958: 46–47. C, Sauskan, V. I., and V. P. Serebryakov, 1968: fig. 6. D, Kuntz, A., and L. Radcliffe, 1918: fig. 55.*)

21.1, and incompletely formed at 22.5 mm. Pelvics formed and with rays at 9.93 mm, reaching anus at 15.3 mm. Notochord oblique at 9.93 mm.[40]

Pigmentation: Three postanal pigment bands, typical of yolk-sac larvae, evident at ca. 11 mm.[7,24] At 4.0–9.0 mm these bands fail to merge over the back, thus appearing, in dorsal view, as pairs of pigmented areas (a character which separates them from larvae of *Centropristis striata*).[20] At 6.5 mm dorsal region of abdominal cavity heavily pigmented, large black melanophores on dorsal aspect of head and anterior region of trunk.[8] At 9.93 mm additional pigment in front of eyes, beneath pectorals, near dorsal fin, and near end of tail.[40] At 11.0 mm dorsal region of abdominal cavity heavily pigmented, large melanophores along entire dorsum except in caudal region.[8] At 12.1 mm pigment appears on both jaws, caudal and dorsal melanophores increase, and melanophore developing at base of caudal rays. At 15.3 mm



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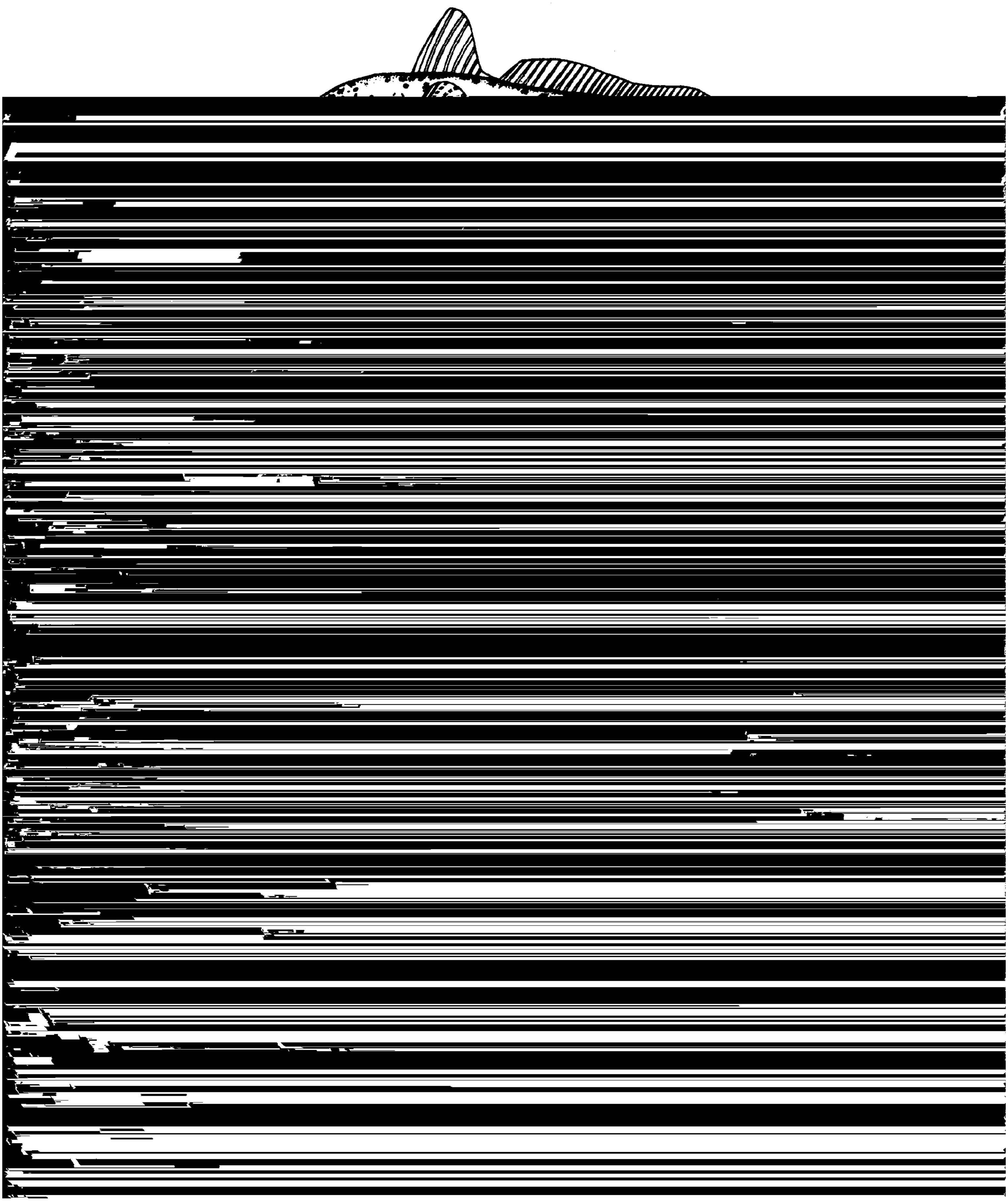

pigment increased on jaws, beneath pectoral fins, and on peritoneum. A cluster of melanophores at base of caudal, and 2 large melanophores on last 3rd of 2nd dorsal and anal. At 22.5 mm dorsal and dorsolateral aspects of body with scattered melanophores, pigment developed on first dorsal, caudal, and pelvics.[40]

10. Leim, A. H., and W. B. Scott, 1966:205–8.
11. Altman, P. L., and D. S. Dittmer, 1962:479.
12. Mansueti, R. J., 1962a:3.
13. Hildebrand, S. F., and W. C. Schroeder, 1928:162–4.
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Apeltes quadracus
Gasterosteus aculeatus

sticklebacks
Gasterosteidae

FAMILY GASTEROSTEIDAE

This family is found throughout most of the northern hemisphere, occurring approximately between the 30th parallel and the Arctic Circle. Its various members occur collectively in fresh, brackish, and marine waters, and several species are anadromous. Typical habitats include streams, creeks, ponds, lakes, marshes, estuaries, tide pools, and the open ocean. The family consists of five genera and about eight species.

The three-spined stickleback, *Gasterosteus aculeatus*, one of the two regional members of the family, appears to consist of two distinct forms, apparently reproductively isolated: the migratory marine form (*trachurus*) and the non-migratory freshwater form (*leiurus*). The status of these two populations is still unclear. In the present review both populations are considered part of the "*aculeatus*-complex" as defined by Nelson (1971). This complex may, in fact, include a number of geographically and/or reproductively isolated species.

In the sticklebacks the caudal peduncle is typically long and the body laterally compressed. Bony lateral scutes may be present or absent. The teeth are small but well-developed. The circumorbital ring is incomplete posteriorly. Sticklebacks have three branchiostegal rays, and a series of up to 16 well-developed isolated dorsal spines in advance of the soft dorsal fin. The caudal fin is round or very slightly forked. One pelvic spine is present (although in some populations the pelvic fins are entirely lacking), and there are 27 to 42 vertebrae. Complex nesting behavior and parental care of the eggs and young are important characteristics of the family.

Male sticklebacks construct elaborate nests of aquatic vegetation, which are held together by a thread-like material secreted by the kidney. In *Gasterosteus aculeatus* the nest is on the bottom, sometimes over a shallow evacuation. In all other species, the nests are generally off the bottom. After courtship and spawning the male remains with the eggs to aerate them and protect them from predators. Aeration may be accomplished either by fanning or by blowing water through the nest. A male *Apeltes quadracus* may guard up to four nests simultaneously. In this species, if eggs fall from the nest during spawning they are immediately recovered by the male. Males of *Gasterosteus aculeatus* remove dead eggs from the nest.

In the regional sticklebacks the eggs are demersal, vary from 1.0 to 2.0 mm in diameter, and have a number of oil globules of various sizes. In both species the perivitelline space is relatively narrow. *Apeltes quadracus* eggs are reported to have adhesive threads on the chorion, while the chorion is smooth in *Gasterosteus aculeatus*. Eggs of *G. aculeatus* adhere to one another, but their adhesiveness to other objects is apparently variable. The eggs of this species may have significantly more oil globules than the somewhat smaller eggs of *Apeltes quadracus*.

Larvae of *Gasterosteus aculeatus* hatch at 3.0 to 7.0 mm; those of *Apeltes quadracus* at 4.2 to 4.5 mm. In larvae of both species the mouth is open at the time of hatching; the pectoral buds are well-developed; the yolk sac is large, oval, and has a well defined vitelline circulation pattern. The finfold is relatively low and not extended forward to the head. Pigment is present at least on the body. Throughout the larval period the anus lies at a point between two-fifths and three-fifths of the distance to the tail.

Apeltes quadracus (Mitchill), Fourspine stickleback

ADULTS

D. II to VI, 9–14 [5] (3 or 4 isolated spines + 1 at beginning of soft dorsal [42]); A. I,[27] 7–11; [5] C. 13; P. 11 [24]–12; [42] V. I, 2; [26] vertebrae 29 [42]–34; [26] branchiostegal rays, 3.[42]

Proportions expressed as times in TL: Head 3.4 [19]–4.5,[26] depth 3.6 [27]–6.0.[26] Eye 25.0–33.3% HL.[42]

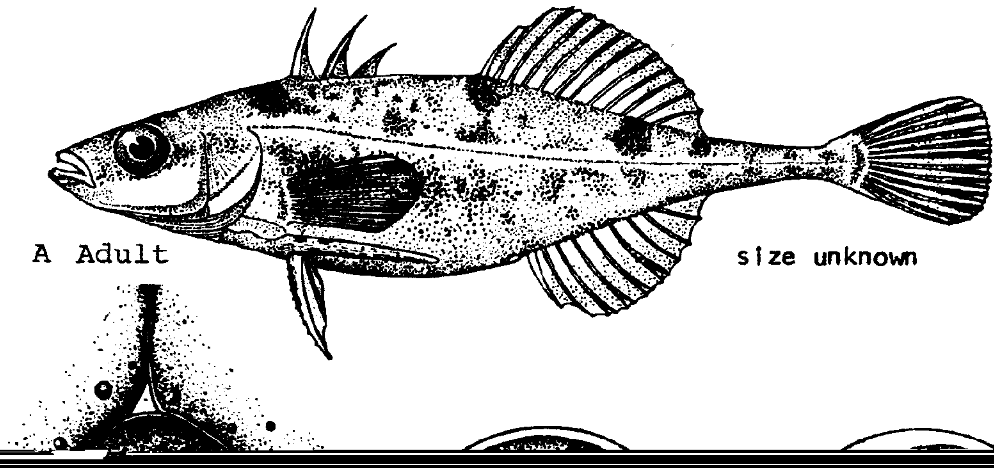
Body fusiform,[12] elongate, compressed, triangular, flat-bottomed in cross-section; back elevated at beginning of rayed dorsal; caudal peduncle long, slender; head rather long; snout pointed; mouth small, slightly oblique, nearly terminal; maxillary failing to reach eye. Teeth slender, small, in single series.[16,19,27,28] Scales absent. Innominate bones not joined, no bony plate between pelvics.[12,14,26]

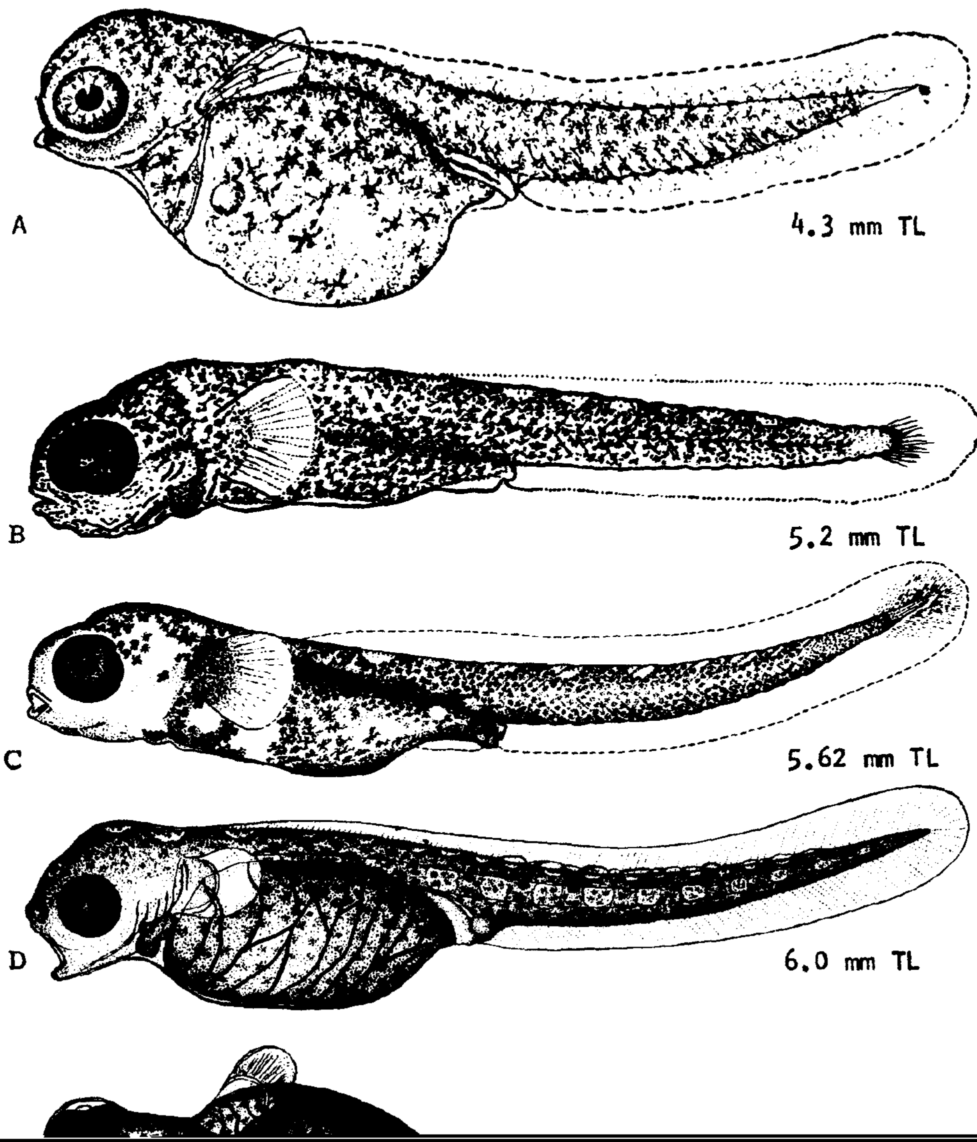
Larvae—in relatively shallow water near mouth of Patuxent River, Maryland (WLD); various localities in Mystic River, Connecticut, having average annual salinities of 3.0-ca. 22.0 ppt.[38]

Juveniles—abundant in upper Mystic River, Connecticut, in summer; [38] probably restricted to place of origin, although young reported from tidal currents at Woods Hole, Massachusetts; [21] in surface collections in vicinity of Woods Hole.[22] From various localities with average annual salinities of 3.0–ca. 30 ppt.[38]

SPAWNING

Location: In nest [12] in brackish waters [17] of weedy shal-


A Adult
size unknown


A
4.3 mm TL
B
5.2 mm TL
C
5.62 mm TL
D
6.0 mm TL

48 hours—tail tip rounded, body segmented, auditory vesicles and otoliths formed.

4 days—large black melanophores over entire surface of embryo and in adjacent extra-embryonic blastoderm; small yellow chromatophores on embryo; [30] heart a simple spherical sinus.

4th or 5th day—primary divisions of brain, cerebral vesicles, optic cups, and pectoral buds formed.

7 days—heart pulsating.

Just before hatching—sides blotched with large brown melanophores, intestine greenish.[8,18]

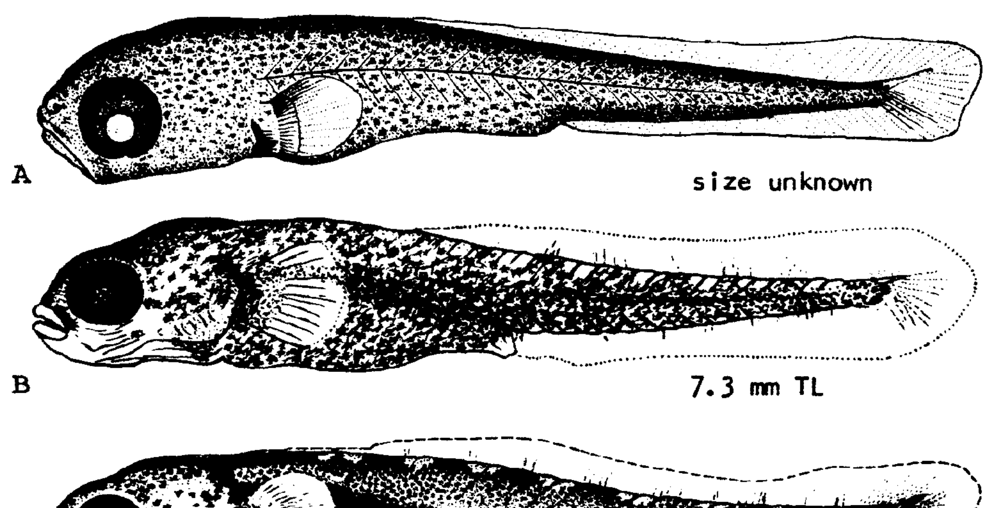
Incubation period: 6 days at 22 C.[17]

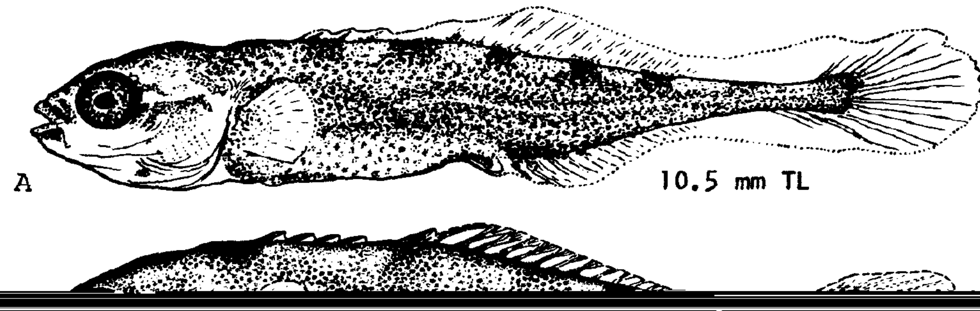
YOLK-SAC LARVAE

Hatching length 4.2–4.5 mm [17,30] (although a specimen of 6.0 mm TL is described as recently hatched [8]); average 4.3.[35] Maximum size described 8.4 mm (WLD).

Body deep, stout (WLD); at 4.3 mm mouth open; yolk initially oval,[30] elongate at 5.2 mm; choroid fissure still evident at 5.2 mm, gill rakers at 7.3 mm (WLD). At hatching, reported to have 10–12 lateral sensory organs surmounted by transparent cells and projecting from general level of body. Pectorals well-developed at hatching; [18] incipient caudal rays at 5.2 mm; preanal finfold obliterated, urostyle oblique at 7.3 mm (WLD). Anus slightly more than one-half length of body from anterior end.[30]

Pigmentation: Similar to *Gasterosteus aculeatus,* but more heavily pigmented.[17,28] At hatching (4.3 mm) ground color dark brown, large black chromatophores over entire surface of body and upper half of yolk, yellow chromatophores sparsely scattered over body [30] (newly hatched larvae of 6.0 mm are also reported with large brown blotches along dorsal line and on sides [8]). At 5.2–7.3 mm ground color dark olive brown to black with 10 or 11 clear blotches along mid-dorsal line between head and tail (WLD).




A
10.5 mm TL

Gasterosteus aculeatus Linnaeus, Threespine stickleback

ADULTS

D. II to V,[80] 6–13; [29] A. I,[42,75] 6 [12]–13 (minimum of 4 experimentally); [17] C. 5–7+6–7; [29] P. 9–11 [61,89] (8 experimentally); [17] V. I,[42,75] lateral plates 0 [44]–37; [103] vertebrae 29 [61]–33; branchiostegal rays 3–4; [22] gill rakers 12 [77]–25; [44] average number of gill rakers on first arch (various populations), outer 19.46–20.59, inner 14.86–16.35.[61]

Proportions expressed as times in TL: Depth 4.0 [96]–5.0,[95] head 3.3 [96]–4.2.[95]

Body moderately slender, spindle-like, tapering to slender caudal peduncle,[12,34] deeper in females than males; [66] head short; [108] snout somewhat pointed.[12] Mouth rather small, oblique, slightly superior; maxillary failing to reach eye.[96,108] Teeth in both jaws sharp, relatively large; [95,101] opercle finely serrate; [108] innominate bones united, forming lanceolate plate on middle of abdomen between and behind pelvics.[43,95] Pelvics sometimes absent,[2,6] spines erectile; [34] anal spine small, detached; [97] posterior edge of dorsal and ventral spines serrated; [42] anal origin well back of dorsal origin; tail moderately forked.[12,97]

Pigmentation: Olive green,[75] greenish brown,[97] brown,[12] dark grayish,[108] silver,[103,122,134] silver-white,[80] blue,[97] bluish black,[38,108] or black [103] above; top of head and back sometimes finely punctuated with black; [105] white,[109] silvery white,[38] silver [95,108] or light below; [12] sides paler than dorsum, silvery or yellowish.[62,78] Dorsum and sides plain [103] or with indefinite brown cross bars and transverse blotches; [12,96] sometimes with irregular greenish blue stripes or bands.[38] Fins generally pale, but with pectoral rays outlined by small black dots,[12] base of caudal sometimes with black bar,[96,108] and anal fin membranes sometimes red.[95] Color of both sexes modified during spawning.[79] Spawning males bluish white,[4] blue,[5] greenish blue,[86] green,[102] gray or creamy brown above; bright vermilion or scarlet red [38,88,109,124,129] to yellowish salmon [12] below, or red tinted over with yellow; [82] rarely jet black throughout.[119] Ventral nuptial pigmentation first developed in region of branchiostegals,[38] variable in extent, sometimes limited to throat [86] (possibly, however, outside spawning season [88]), and at other times in mouth cavity, on throat, cheeks, opercles,

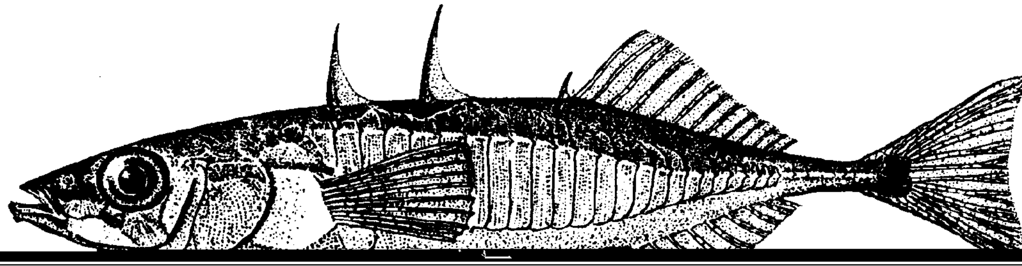
Maximum length: 110 mm or larger,[80,117] with size diminishing southward.[7]

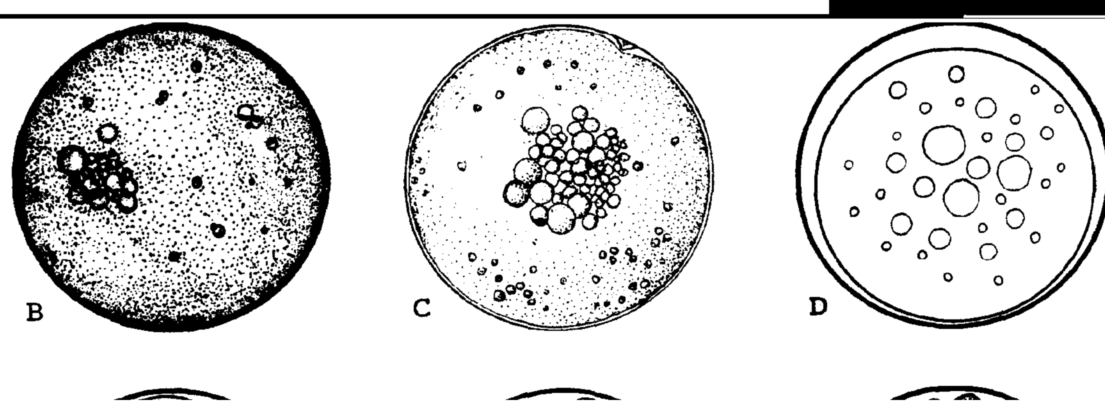
DISTRIBUTION AND ECOLOGY

Range: Fresh and salt waters of northern hemisphere.[26] In eastern North America, the Strait of Belle Island, Newfoundland,[97] and the Hudson Bay region,[34,58] west along the Arctic Islands of Canada; [115] south through Manitoba [58] to vicinity of Lake Ontario and Atlantic coast to lower Chesapeake Bay [34,97] or, possibly Cape Hatteras; [80,83] in western North America from western Alaskan Peninsula south to Rio Tijuana, Mexico.[83] Greenland [52,76] and Iceland.[55] In Europe, northern Norway and Sweden; the Baltic and North Seas; England and Ireland; the Hebrides, Orkneys, and Shetland Islands; Faroe Islands; all of central Europe except the Alps; [30,83,102] south to Spain and Portugal; along the Mediterranean to Sardinia, Italy,[83] Turkey,[57] and Syria; the Black Sea and Sea of Azov; [83] along Arctic Ocean from Murmansk and Novaya Zemlya [53] to Bering Straits.[80] In North Africa once recorded from Algiers, but this population no longer extant and possibly based on introduction.[76,89] In western Pacific and Asia from Aleutian Islands and islands of central Bering Sea to Kamchatka, the Juril Islands, Japan, Korea [66,83] and western China.[26]

Area distribution: Maryland; [43] Virginia; [96] Delaware; [25,107] the Delaware River estuary; [92] seaside of Maryland and Virginia; [15,96,131] north in Chesapeake Bay to Cape Charles City and Hampton, Virginia.[96]

Habitat and movements: Adults—occupy a wide variety of habitats from the open sea to inland waters up to at least 700 km from coast,[3,32,97,98] and with different populations apparently occupying different habitats.[125,134] Usually in shallow water.[12] In freshwater in rivers, brooks,[38,61,75] streams (at elevations of up to 183 m),[32,75] canals,[48] ditches,[70] landlocked lakes,[8,76] ponds,[24] open glades covered with duckweed,[15] paddy fields,[66] warm springs, peat evacuations (to which eggs were probably carried by flooding), and artesian wells to depths of up to 128 m.[23,80] Sometimes stranded in large numbers in temporary forest pools.[60] In streams in dense vegetation




B
C
D

Larvae—during first 2 hours lie on side, but capable of swimming toward surface; after 2 hours can remain upright.[13,16] Remain in nest for 1 [72]–2 days, and herded by mouth by male parent.[4,78,82,94,106,124] Positively phototrophic.[133]

Juveniles—in schools soon after leaving nest and while still under influence of male parent.[78] Young reported from weed beds in rivers; [5] also in streams, lakes, and paddy fields among aquatic vegetation; [38,134] and in brackish water ditches; [48] freshwater lagoons,[127] and coastal rockpools.[126] Specimens with average SL of 16 mm in 2.4 m of water 0.2 km from nearest vegetation.[47] Schools of up to 500 individuals reported in canals and ditches.[82,106] In salt water remain in pelagic schools until 25 mm long, then near bottom among aquatic vegetation.[86] In Japan (and other areas) juveniles assemble in large schools in summer and early fall and migrate toward sea; in at least some Japanese populations the seaward migration follows scute formation at 22–27 mm TL; [118] remain in estuaries or spread out along coast during winter; [76,91] downstream movement of young begins at length of 18 mm in Elbe River.[83]

SPAWNING

Location: Both brackish and freshwater,[8,86,97] on or near bottom [56,77,81] in water 100 to ca. 500 mm deep,[4,52,77,100] in coves, bays, rivermouths,[70] rivers, small streams,[13,77] ditches,[48,49] lakes,[12] paddy fields,[38] and possibly flooded meadows [77] over bottoms of sand [81] or mud.[77] Often in open water, but usually near or among aquatic plants, such as *Oenanthe, Eleodea, Potomogeton, Nuphor* and *Carex* and possibly *Zostera,* or stones in standing water or in moderate current (up to 6 cm/second).[52,77,94,128] Spawning activity has been observed in polluted water.[51] Maximum recorded salinity, 7.8 ppt,[48] but nest building without spawning has been observed in the North Sea, and eggs have been produced in "Nordseewasser" (although whether in nature or under laboratory conditions is not clear), but hatching may not have occurred.[70]

Nest: Built and guarded by male; variable in shape,

Season: Late February through September throughout range. Mystic River, Connecticut, ripe adults May to July in upper river, June and July in lower; [113] Woods Hole, Massachusetts, May to end of July; [47,97,99] Canada, late February or March to September [77,128] (April to September in British Columbia [34]); California, breeding colors and maturing eggs in late February, nest activity as early as February 13, eggs available until middle of August; [13] Alaska (Kodiak Island), ripe females May 23 to August 3; [12] Greenland, June to July; [13] Ireland, continues to mid-September; [75] England, maturation begins August or September,[36] ripe testes in January,[31] spawning April to mid-August; [24,29,36,65] (Note, however, that in England some males have well-developed testes and red throats throughout year [120]); Scandinavia, March to July or later; [13,86] Netherlands, April to July,[49] with two spawning peaks; [45] France, mid-March to end of July.[38,69] Male gonads may be ripe throughout year in some populations, but nesting behavior will not occur in nature outside normal spawning period; [49] can be induced to spawn almost throughout year under laboratory conditions.[16] Natural spawning period lasts average of 3–4 months.[52]

Temperature: 20 C in experimental tanks; [46] nuptial colors at 17–20 C; [85] nest building experimentally induced at 5 C; gonads developed at minimum of 4 C.[49]

Time: Not definitely stated. Nest building observed during daylight hours (by implication),[53] spawning possibly at night.[28]

Frequency: 5–6 times during 60–90 day period.[82,117]

Fecundity: Mature eggs 50 [4]–292 [77] (a minimum of 3 [94] is questioned, JDH); averages "usually less than 100," [26] 105, and 241, varying from population to population.[77] Ovarian eggs 177–567, mean 320.[27] One female may produce 400–500 eggs (presumably mature) in 20 days.[82]

EGGS

Location: Demersal,[11,14] deposited in adherent clusters in nests, holes in sand, or rocky crevices, or scattered at

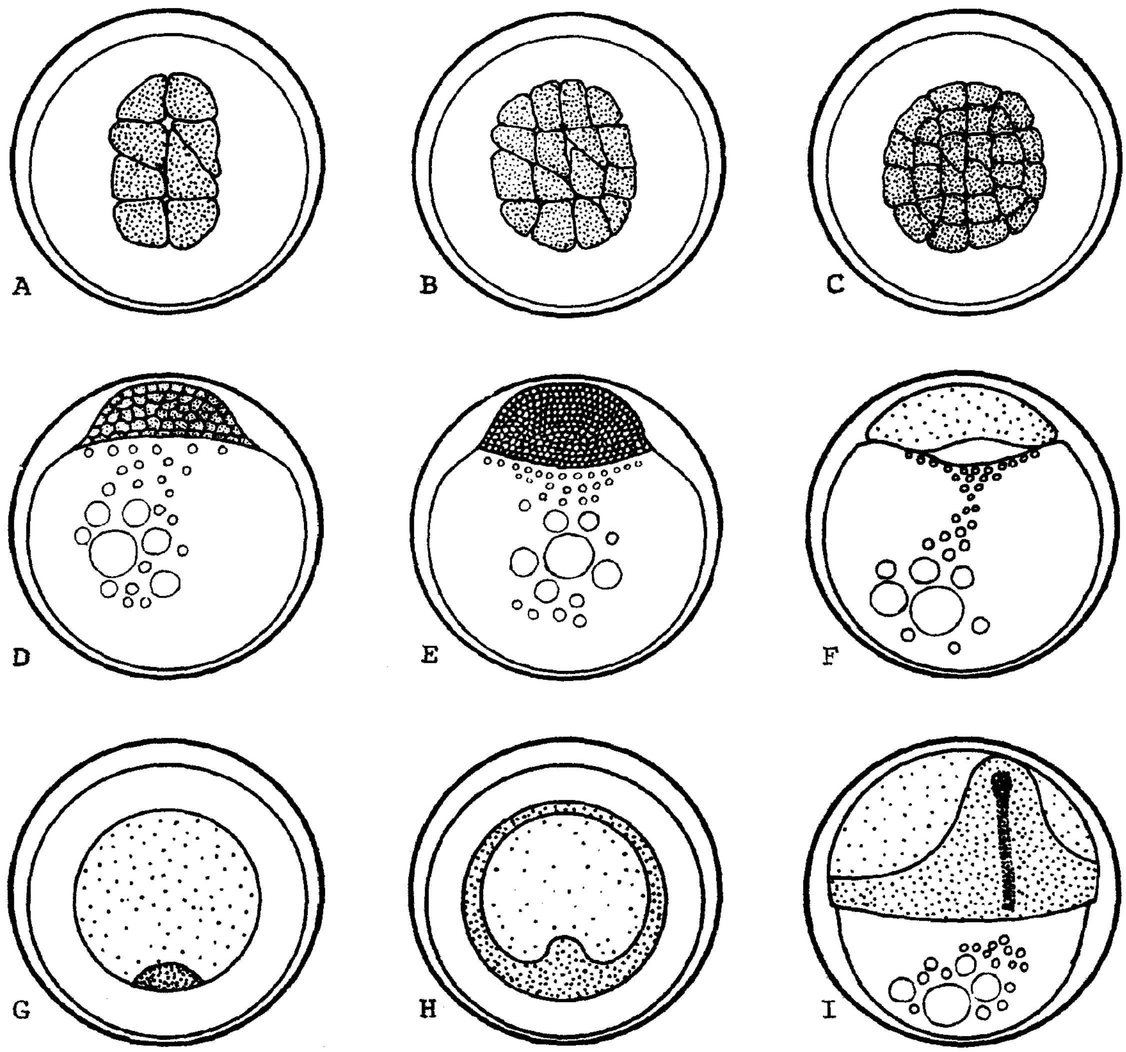
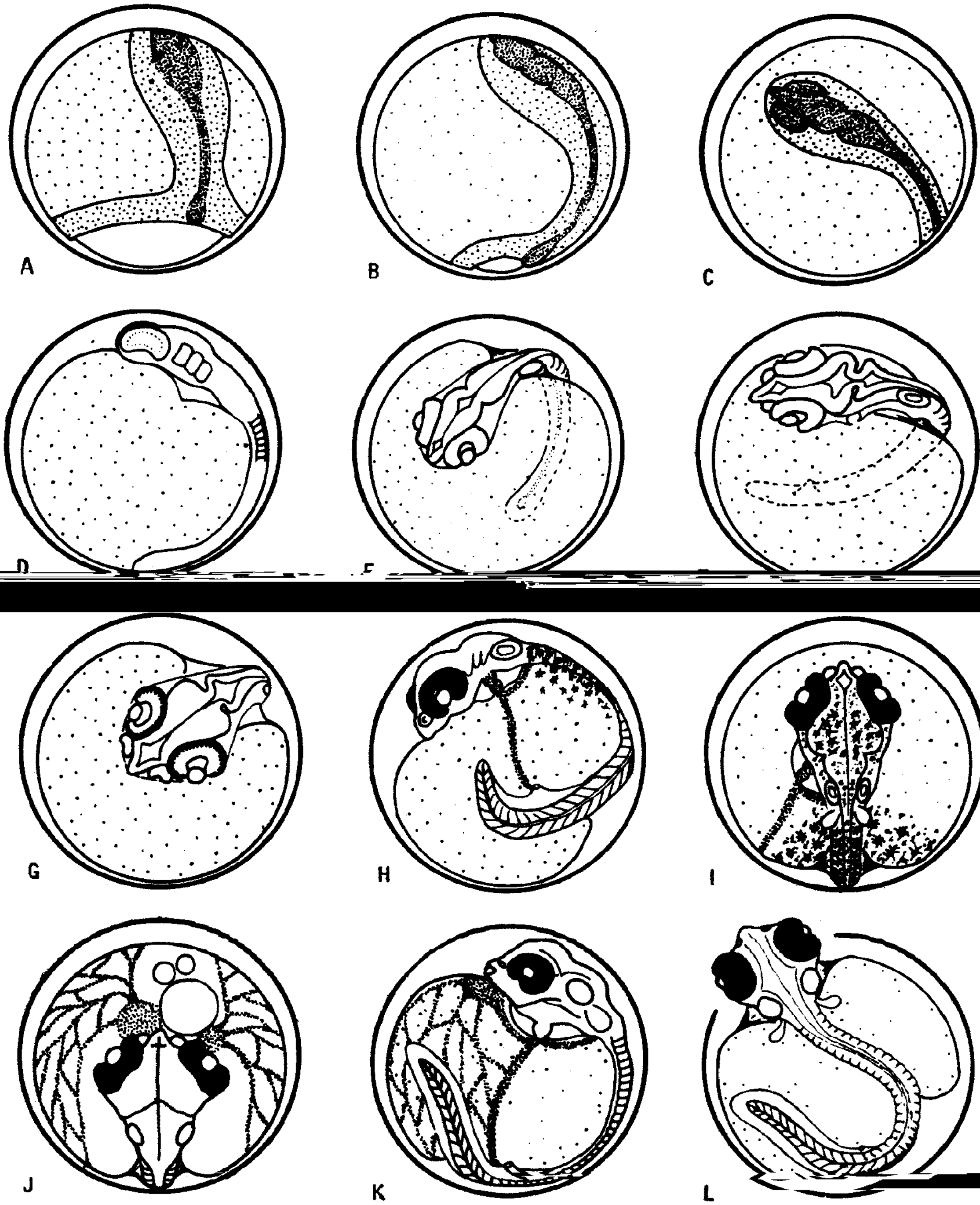


Fig. 209. *Gasterosteus aculeatus,* Threespine stickleback. A. 8-cell stage. B. 16-cell stage, 3 hours and 45 minutes. C. 32-cell stage, 4 hours. D. Early morula, 6 hours. E. Late morula, 10 hours, periblast formed. F. Blastula, 15 hours, blastocoele formed. G. Beginning of invagination (viewed from above), 22 hours. H. Germ ring formation (viewed from above), 26 hours. I. Germ ring one half over yolk, 30 hours. *(A-H, Swarup, H., 1958: figs. 5–13.)*

Fig. 210. *Gasterosteus aculeatus,* Threespine stickleback. A. Germ ring over 3/4 egg, neural plate formed, 36 hours. B. Small yolk plug, brain divisions evident, 42 hours. C. Closure of blastopore, 50 hours. D. 6–7 somites, optic vesicles formed, three blocks of mesodermal tissue formed on both sides of head, 60 hours. E. Lens, brain vesicles, otic capsule formed, Kupffer's vesicle forming, 70 hours. F. Otoliths, olfactory lobes formed, 88 hours. G. Margin of eye pigmented, movement evident in tail, 106 hours. Circulation established, gill slits evident, melanophores on dorsal side of body and adjacent yolk sac, 130 hours. I. Pectoral buds formed, melanophores over entire eye and body, 144 hours. J. Ventricle of forebrain closed, 156 hours. K. Mouth formed, choroid fissure closed, pectoral fins vibratory, 168 hours. L. Hatching stage, hatching occurs head first, 199 hours. *(A-L, Swarup, H., 1958: figs. 14–25.)*


A
B
C
G
H
I
J
K
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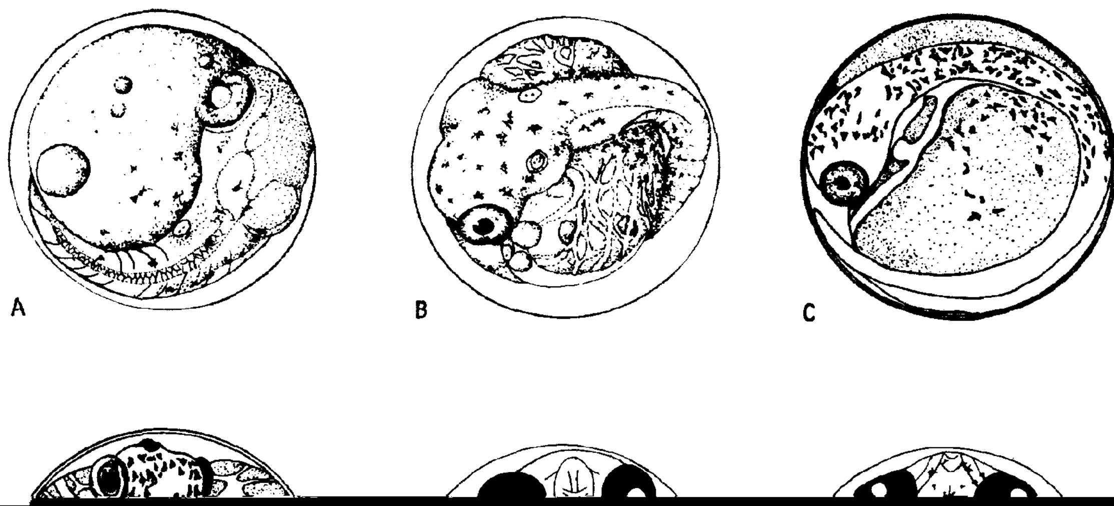

A
B
C

4 hours, 50 minutes to 5 hours, 5 minutes.	8–cell stage.
5 hours, 30 minutes.	16-cell stage.
6 hours, 10 minutes.	32-cell stage.
21 hours, 20 minutes.	Late segmentation, disc beginning to spread.
23 hours, 45 minutes.	Germ ring established.
26 hours, 5 minutes.	Embryonic shield formed.
31 hours, 5 minutes.	Blastoderm over 1/2 yolk.
42 hours, 35 minutes.	Blastopore closed.
56 hours, 5 minutes.	Embryo well-developed, eyes and brain established.[112]

Development at unspecified temperature (Kuntz and Radcliffe series): [99]

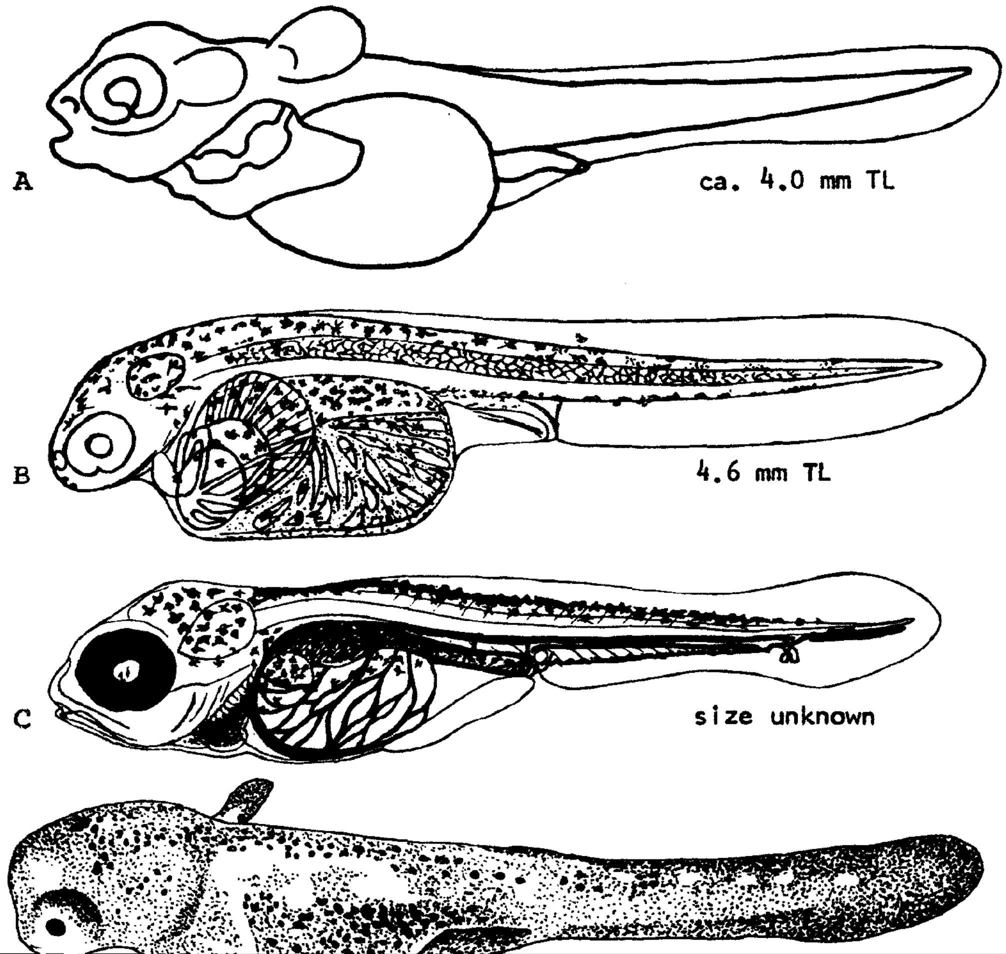
24 hours.	Embryo well differentiated, blastopore closed.
68 hours.	Embryo nearly equal to circumference of yolk, head relatively broad, body tapering gradually to posterior end, circulation established in extraembryonic blastoderm. Small melanophores on dorsal surface of anterior region of trunk and in-

Incubation period: 4 to ca. 40 days, depending on temperature [59] (and possibly other factors, JDH); at 6–7 C, ca. 40 days; [59] at average of 8.8 C, average of 15 days, 8 hours; [52] at 9–16 C, eyed in 9 days, hatch in 14; [12] at 17+0.6 C ca. 5 days, 20 hours; [13] at average of 17.8 C, average 8 days, 15 hours; [52] at 18–20 C, 6–8 days; [16,65,83] at 26 C, 4–5 days; [59] at "laboratory temperature," ca. 6 days.[99] Effects of environment on incubation: mutually exclusive adaptive peaks with regard to effects of temperature and salinity can be demonstrated for eggs of salt and freshwater forms.[29,74] Eggs from southern Europe develop more rapidly at higher temperatures (12–25 C) than eggs from northern Europe, more slowly at lower temperatures (8 C).[68] Optimal (normal) temperature range, 15–19 C. [11] Although hatching may not occur naturally in seawater,[13,70] eggs have developed "fairly well" in experimental tanks at salinity of 44 ppt.[68]

YOLK-SAC LARVAE

Hatching length 3.0 mm [16] or possibly smaller (some specimens of this size are 6 days old) [52] to ca. 7.0 mm.[86] Size at end of stage 12 mm.[39] Duration of stage 3 [97,98] to 7 days,[99] depending on temperature, ca. 4 days at 18–19.[15]

Body relatively deep, head either closely attached to yolk or free at hatching; mesencephalic flexure conspicuous; yolk mass deeply oval at hatching [13,16] (in a specimen 36 hours old, deeper than long [71]) or elongate,[59] half absorbed in 24 hours (ca. 4.0 mm); [16] yolk with single large oil globule; [56] mouth open [16] or not open and evident only as slight depression at hatching; [13] choroid fissure still


A
ca. 4.0 mm TL
B
4.6 mm TL
C
size unknown

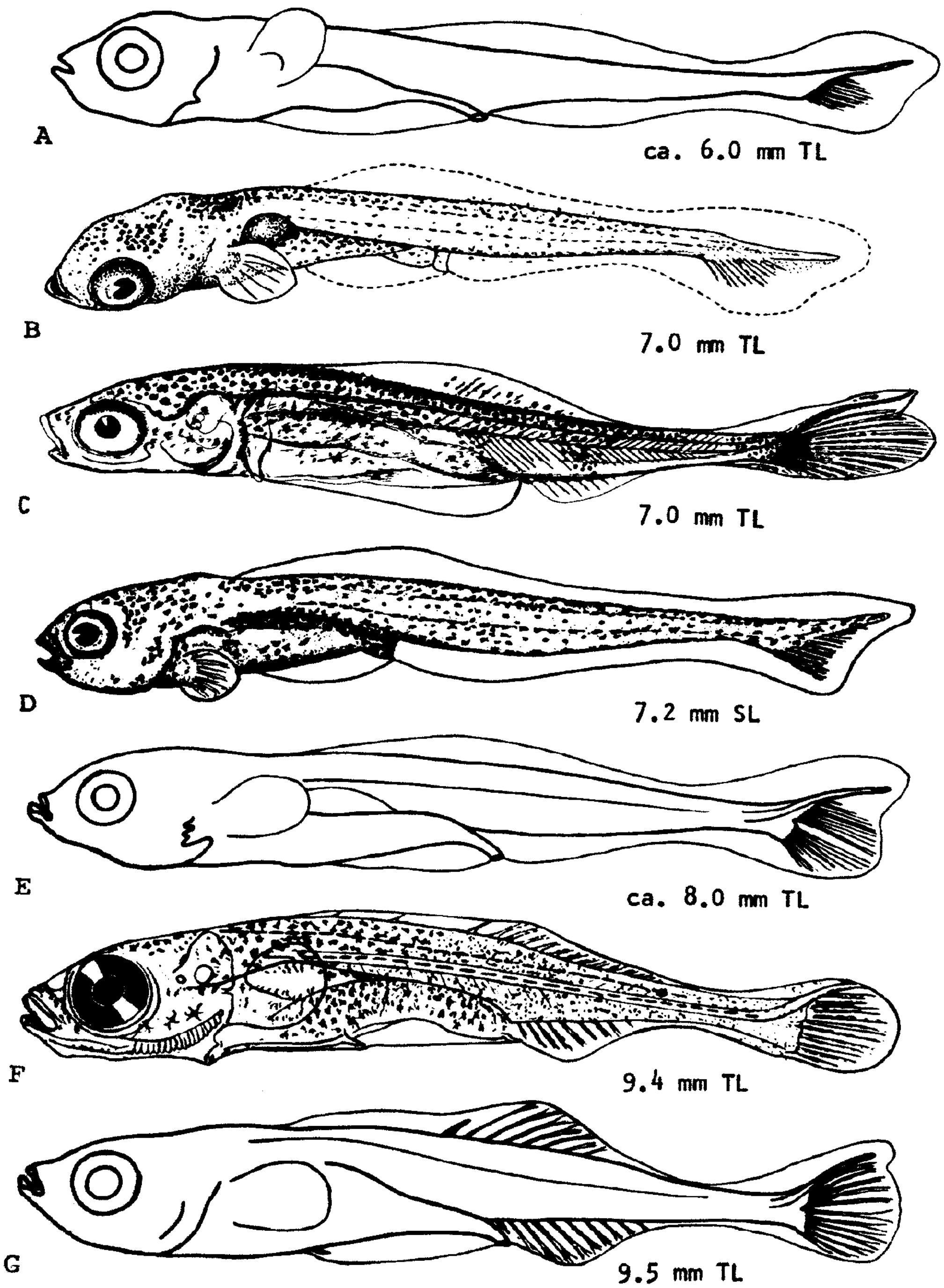


Fig. 214. *Gasterosteus aculeatus,* Threespine stickleback. A. Larva, ca. 6.0 mm TL, 4 days old. B. Larva, 7.0 mm TL. C. Larva, 7.0 mm TL. D. Larva, 7.2 mm SL, 6 days. E. Larva, ca. 8.0 mm, 9 days. F. Larva, 9.4 mm TL. G. Larva, 9.5 mm, 16 days. (*A, E, G, Swarup, H., 1958: figs. 28–30. B, Kuntz, A., 1882: pl. 9. D, Vrat, V., 1949: fig. 14. F, Ehrenbaum, E., 1905–1909: fig. 115.*)

head. At 4–6 days entire body cinnamon brown; melanophores darker, concentrated. At 7 days incipient anal rays brown, lower jaw still transparent.[51]

evident at ca. 8–ca. 9.5 mm, first anal spine at ca. 9.5 mm. At 9.5 mm dorsal and anal separated from caudal, triangular in shape.[16] Caudal either homocercal [116] or

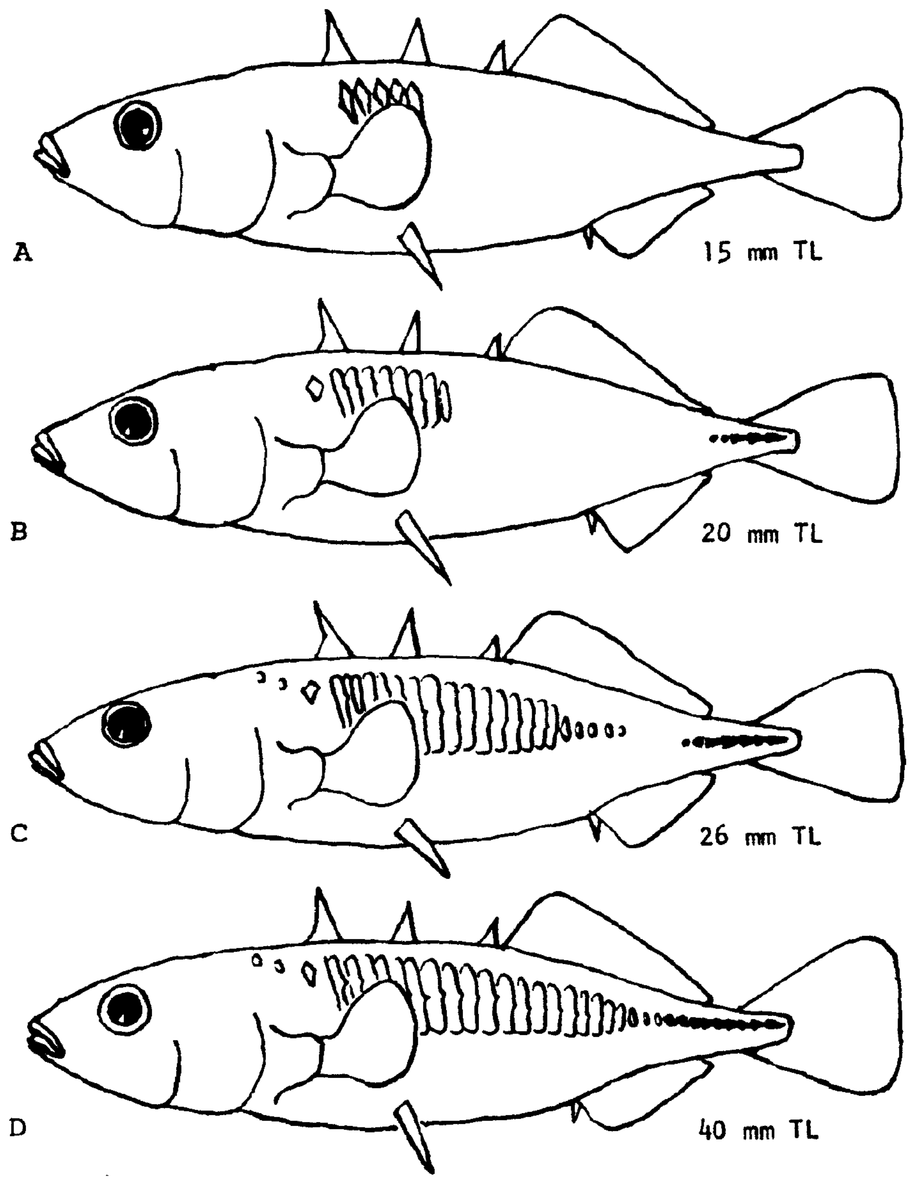


Fig. 217. *Gasterosteus aculeatus*, Threespine stickleback. Development of scutes in landlocked stickleback (*Gasterosteus aculeatus aculeatus*). A. 15 mm TL, scutes evident only in region above pectoral fin. B. 20 mm TL, scutes forming on caudal peduncle. C. 26 mm TL. D. 40 mm TL, scute formation complete. (*A-D, Igarashi, K., 1964: fig. 1.*)

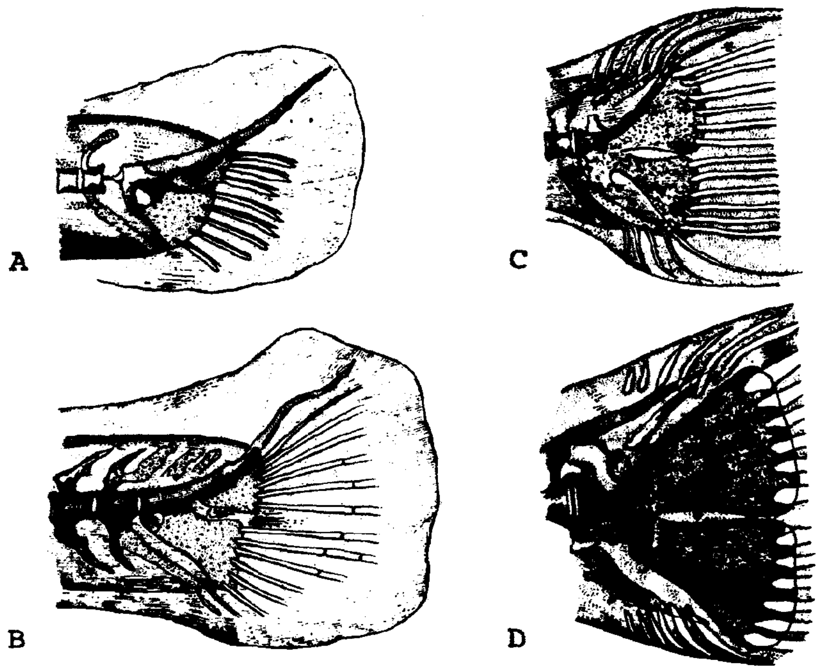


Fig. 219. *Gasterosteus aculeatus*, Threespine stickleback. Development of caudal skeleton. A. 7.60 mm TL, urostyle well-developed, oblique. B. 10.64 mm TL, primary caudal rays developed. C. Half-grown specimen, size unknown, procurrent rays developing. D. Adult specimen, caudal skeleton complete. (*A-D, Huxley, T. H., 1859: pl. 3.*)

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Fistularia petimba

Fistularia tabacaria

FAMILY FISTULARIIDAE

Cornetfishes occur in tropical and subtropical waters throughout the world. One species, *Fistularia tabacaria,* has been reported as far north as Nova Scotia. The family contains four species, two of which (*F. commersonii* and *F. tabacaria*) occur inshore on reefs and grass beds and two of which (*F. petimba* and *F. corneta*) are found in deeper waters along continental margins.

In these fishes, the body is elongate and depressed; the snout is greatly produced and ends in a small, terminal mouth. The two mid-caudal rays extend as

Fistularia petimba Lacépède, Red cornetfish

ADULTS

D. 13[6]–17,[8] $\bar{x}$ 15.5;[5] A. 13[6]–16,[8] $\bar{x}$ 14.5; P. 15–17, $\bar{x}$ 15.9; V. 6; vertebrae 50 + 26 (4 anteriormost preanals fused).[5]

Preorbital distance 3 times in HL.[1]

Body greatly elongate, much depressed;[8] upper ridges of snout parallel; upper, lateral, and lower ridges of snout, preorbital and postorbital ridges serrate. Spinules in skin well-developed; a single median row of elongate bony plates along back from level of pelvics to base of dorsal and from rear of dorsal toward tail; a similar row of plates along ventral midline.[5] Lateral line with dermal ossifications,[1] the posteriormost with large retrorse spines.[5]

79 hours after morula stage.	30 myomeres, eyes forming.
115 hours after morula stage.	Tail elongate, lens formed.
141 hours after morula stage.	Pigment on body, otoliths formed. (Pigment in advanced embryos apparently includes both melanophores and xanthophores.)
152 hours after morula stage.	Hatching.[2]

YOLK-SAC LARVAE

Hatching length, 7.08 mm TL.

Preanal myomeres 53, postanal myomeres 33; but varia-

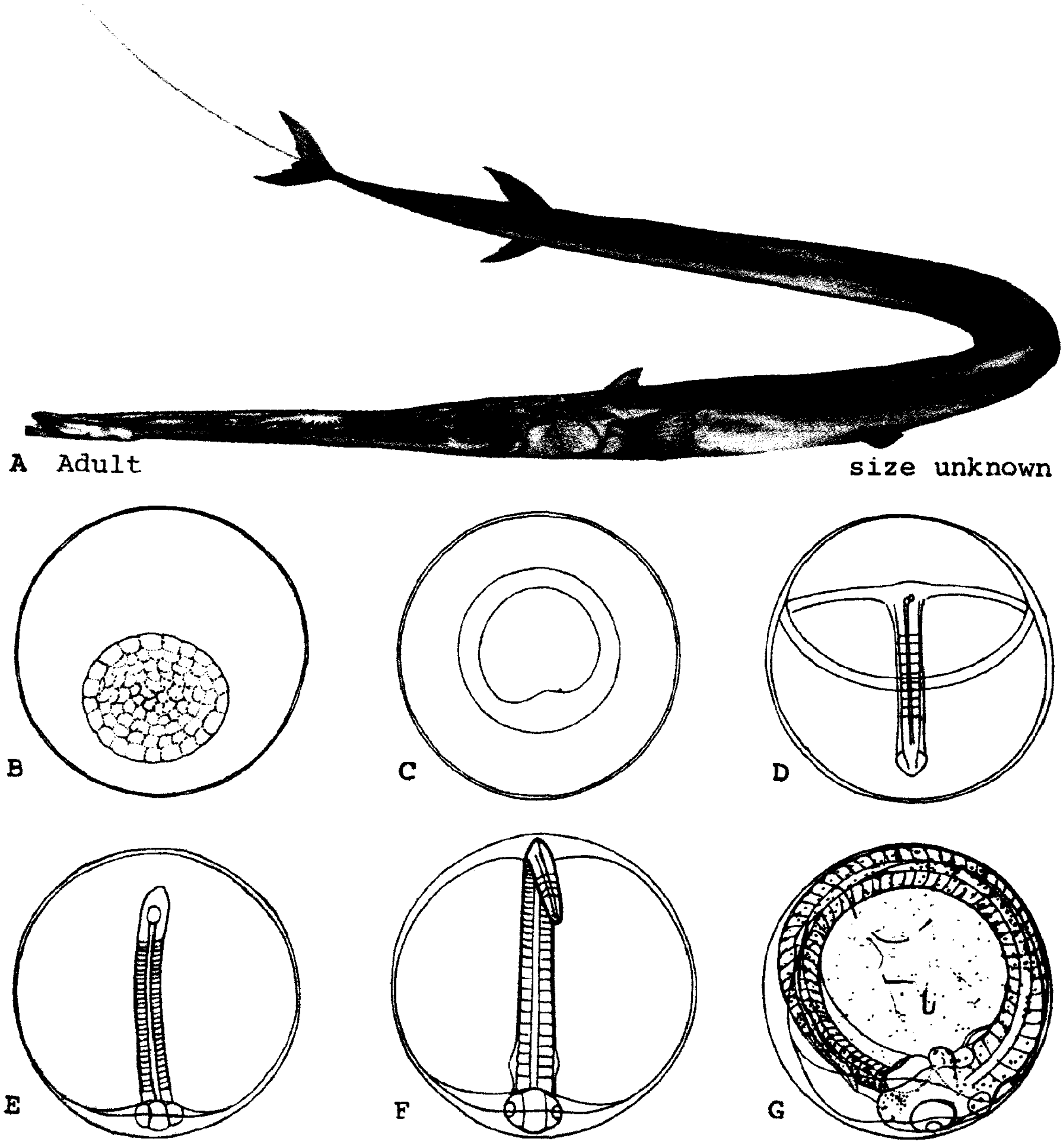

Fig. 220. ***Fistularia petimba***, Red cornetfish. A. Adult, size unknown. B. Egg 5 hours after collecting, morula. C. 29 hours after collecting, gastrula. D. 60 hours after collecting, 9 myomeres. E. 84 hours after collecting, 30 myomeres. F. 120 hours after collecting, lens formed, tail apparently free. G. 141 hours after collecting (11 hours before hatching), pigment, otoliths developed. (*A, Grant, E. M., 1965: 79. B-G, Mito, S., 1961: pl. 34, figs. 5–10.*)

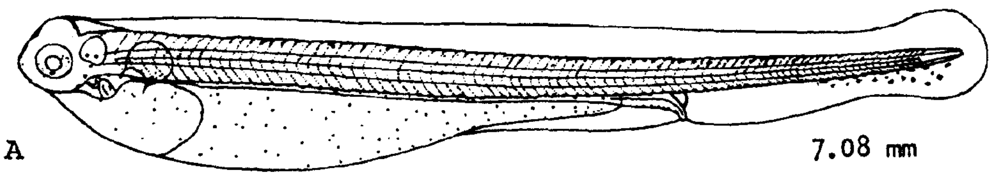

Fig. 221. *Fistularia petimba,* Red cornetfish. A. Yolk-sac larva, 7.08 mm TL. (*A, Mito, S., 1961: pl. 34, fig. 11.*)

Fistularia tabacaria Linnaeus, Bluespotted cornetfish

ADULTS

D. 13[16] or 14[3,14,33]–18,[22] $\bar{x}$ 14.9;[33] A. 13[3,6,9] (a minimum of 11[26] is questioned, JDH)–7,[22] $\bar{x}$ 14.8; C. 14 (7+7); P. 15[33]–17,[5] $\bar{x}$ 15.6;[33] V. 6;[4,5] lateral line pores 100;[22] branchiostegals 5; vertebrae variously counted, 4+49+34 (the first 4 fused),[33] 4+52+31, 4+49+33, 56+33.[35]

Proportions as times in TL (all data presumably not including caudal filament, JDH): Head 2.6[9]–3.0,[36] depth 28–37.[18] As times in HL: Depth 9.8–15.0,[9] eye 14.0.[34] Mandible ca. 4 times in snout.[21,24] Distance from opercle to pelvic fin origin more than twice pelvic fin to anal fin distance.[33]

Body elongate, slender, depressed,[1,9,26] oval in cross section;[5] head depressed;[1] quadrate in vicinity of eyes, slightly broader than deep;[18] snout very long,[1] tubular;[34] mouth slightly oblique, lower jaw projecting in front of and overlapping upper.[1,26] Teeth minute, crowded together in rows.[26,34] Ridges of snout entirely smooth; upper snout ridges parallel; postorbital ridge with some indications of serrations; preorbital and posttemporal ridges smooth; interorbital narrow, with smooth depression.[33] Opercles with fine radiating striae; gill openings extending forward to middle of eye.[1] Eye oval;[31] orbits with angular processes or spines.[4] Scales lacking;[10] spinules in skin not visible.[33] Lateral line distinct.[18,34] Dorsal and anal fins subtriangular, with pointed tips, height equal to that of caudal lobes;[36] dorsal fin inserted at point about one fourth distance between middle of eye and base of caudal, its middle ray the longest; anal fin opposite and equal. Pelvics proportionately small.[1,19] Caudal forked,[9] and with elongate median filament.[10]

Pigmentation: Brownish,[4,33] greenish brown,[9,19,34] or olive[38] above (reports of dark red,[26] reddish,[34] or reddish brown dorsal pigment[21] are questioned, RAF) with a series of unequal, oblong, pale blue spots extending to dorsal fin.[1,24,33] Sides semidiaphanous,[4] and with series of large, oblong blue spots.[26,34,38] Two lateral rows [redacted]

Area distribution: Cape Charles and Hampton Roads, Virginia;[18] Maryland and Virginia seaside bays;[32] Indian River Bay, Delaware;[13] New Jersey.[1,7]

Habitat and movements: Adults—typically an inshore species,[14,23,28,29,39] although recorded from water 32–36 m deep.[12] Taken over sandy, stony bottom among shells and sea fans at depths of ca. 20–25 m[31] (a depth record of 128 m[19] is questioned, RAF); also over "seagrass beds."[39]

Apparently a seasonal visitor in temperate waters: Recorded in North Carolina in September and November;[15] in Chesapeake Bay in "summer and early fall";[18] in New York and Woods Hole from September to November;[8] and in Canadian waters in September.[27]

Larvae—a 16.0 mm larva recorded in surface water approximately 400 km off the coast of Africa at a salinity of 34.96 ppt and a temperature of 25 C.[37]

Juveniles (including specimens up to ca. 200 mm)—recorded inshore[20] and at surface floating above sparse growths of turtle grass.[22]

SPAWNING

Season: The smallest larva thus far collected was taken in tropical waters in February.[37]

EGGS

No information.

EGG DEVELOPMENT

No information.

LARVA

[redacted]

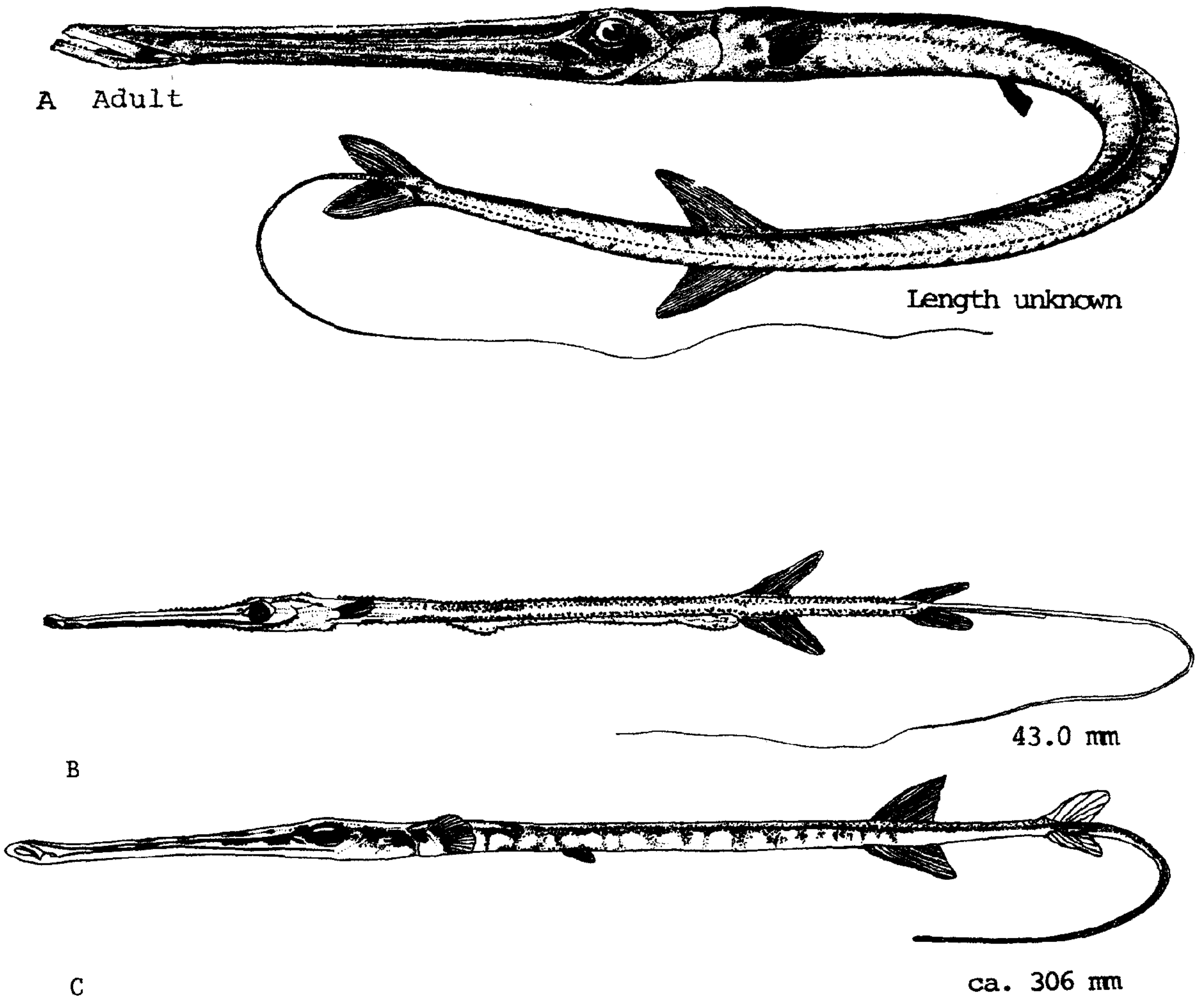

Fig. 222. *Fistularia tabacaria,* Bluespotted cornetfish. A. Adult, length unknown. B. Juvenile, 43.0 mm (excluding caudal filament of ca. 42.0 mm). C. Juvenile, ca. 306 mm. *(A, Leim, A. H., and W. B. Scott, 1966: fig. 175. B, Jungersen, H. F. E., 1910: pl. 7, fig. 1. C, Böhlke, J. E., and C. C. G. Chaplin, 1968: 175.)*

head and adjoining part of body naked. In a 280 mm specimen spinules still over entire body, most densely developed on tail.[35] In another 280 mm specimen spinules restricted to posterior part of body and tail.[36] Disappearance of spinules variable. In a specimen of ca. 350 mm limited to area below lateral line on tail; in another specimen ca. 400 mm long sides and venter with spinelets still well-developed.[35] At 415 mm spinules still evident on tail.[36] A series of "short spindle-shaped ossicles" on forward part of body and to end of tail below and parallel to lateral line (lateral line ossifications? JDH) first evident at ca. 280 mm.[35] Pectoral and pelvic fins

AGE AND SIZE AT MATURITY

Unknown, but Jungersen regards specimens lacking spinules (thus longer than 415 mm) as adults.[35]

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Macrorhamphosus scolopax

snipefishes
Macrorhamphosidae

FAMILY MACRORHAMPHOSIDAE

Members of this family occur in tropical, subtropical, and temperate waters of the Atlantic, Pacific, and Indian oceans. They are relatively small pelagic fishes (up to about 250 mm) and are found in both mid-ocean and coastal areas. At least one species, *Centriscops obliquus,* swims backward as well as forward and normally assumes a striking head-down position.

In the snipefishes, of which there are three or four genera and about 11 species, the body is compressed and deep, the snout is elongate, the second dorsal spine is greatly projected, and there are usually distinct bony plates on each side of the back which form an imperfect exoskeleton.

The family is represented in the Mid-Atlantic Bight by a single species, *Macrorhamphosus scolopax.* This species is wide-ranging and includes the formerly recognized species *M. sagifue, M. japonicus,* and *M. gracilis.*

Ripe ovarian eggs of the regional species (*M. scolopax*) are held together by a common gelatinous mass. After deposition, which is so far known only to occur in March, the eggs float singly. They are relatively small (1.0 mm) and have a rose or violet yolk and a single, large, amber-rose oil globule.

In recently hatched young the yolk is elongate, somewhat tubular, and relatively small. The larvae are characterized by a low preanal myomere count (10), and a broad finfold which is often pigmented and often extends on to the head. The anus varies in position from slightly more than one-half to slightly less than two-thirds the body length. In advanced larvae spines develop on the preopercle and on various parts of the head and trunk.

Early juveniles (prejuveniles in the present account) are characterized by blue dorsal and silvery lateral and ventral pigment. Juveniles 35 mm long or longer have a ground color of reddish brown to brick red.

Macrorhamphosus scolopax (Linnaeus), Longspine snipefish

ADULTS

D. IV to VIII,[15] 10 [3]–13;[15] A. 17 [3]–19;[5] C. 6–7 + 9 + 6–7,[25] also to total of 25;[17] P. 14–17;[5,31] V. 4 [25]–6;[5] vertebrae 8 + 16 [20] = 23–24.[27]

Proportions expressed as times in TL: Depth at front of eye 3.7, greatest depth (occurring at anus) 4.9,[1] head 2.5.[19] Ratio of body height to TL 3.8–5.4 depending on age.[6]

Body strongly compressed and covered with small striated scales, each stria terminating in a rather strong spine, and with bony plates arranged in definite longitudinal rows. Teeth lacking. Origin of first dorsal beyond midpoint of body;[16] 2nd dorsal spine strongly serrated on posterior margin.[19,24]

Pigmentation: Pinkish, rose, red, or reddish olive above; silvery on sides and belly; sometimes golden above.[15,16,18,19]

Maximum length: Ca. 200 [15] to possibly 300 mm TL.[23]

DISTRIBUTION AND ECOLOGY

Range: Worldwide in tropical and temperate waters.[22] In western Atlantic from the Gulf of Maine [2] to Brazil or Argentina;[22] in the eastern Atlantic from Norway [20,21] and southern coast of England [5,9] to Morocco,[16] including the Mediterranean.[2]

Area distribution: Coastal waters of New Jersey in 128 m;[12,13] Delaware Bay at Deadman Shoal,[10] and off Delaware coast at average depth of 25 m;[14] in Virginia coastal waters over continental shelf near mouth of Chesapeake Bay.[13,27]

Habitat and movements: Adults—pelagic,[8,22] found both in mid-ocean and coastal waters [26] at depths of ca. 5 [10] to 310 m;[9] reported in shallow water over "gritty" [1] and muddy bottoms; sometimes associated with *Capros asper*.[28] Temperature range 17–21 C. In some areas concentrate at surface during daytime and move to somewhat deeper water at night.[32]

Larvae—pelagic,[30] and in surface currents,[4,28] particularly at night.[33]

Juveniles—at surface [2] particularly during daylight hours;[33] sometimes associated with jellyfish.[7]

SPAWNING

Location: Ripe females from shallow, muddy water in Italy.[28]

Season: In the Mediterranean ripe ovaries in January,[4,28] eggs in March,[17] larvae 6.0–20.0 mm long in March and April.[28]

Fecundity: Unknown.

EGGS

Location: Apparently float at surface.[28]

Ripe ovarian eggs: Transparent and with a single large oil globule; held together in ovary by a common gelatinous mass.[28]

Fertilized eggs: Spherical, diameter 1.0 mm,[17] transparent;[4,28] vitelline membrane light amber with grainy reflections; yolk with rose or violet halo depending on

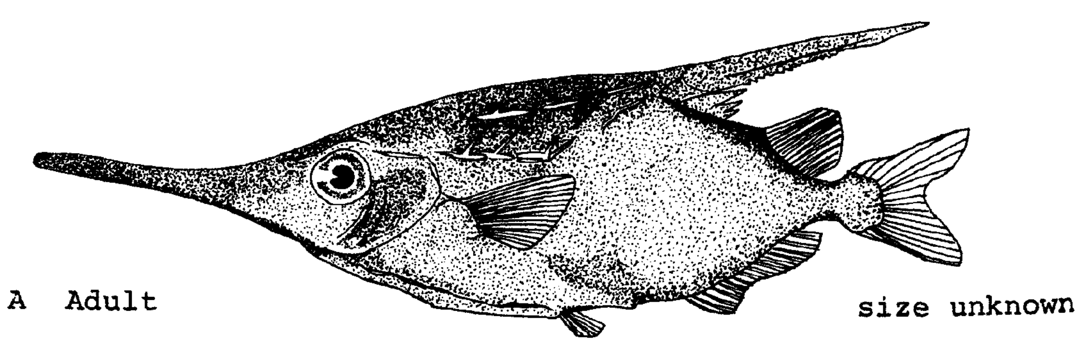


Fig. 223. *Macrorhamphosus scolopax*, Longspine snipefish. A. Adult, size unknown. (*A, Kamohara, T., 1967: pl. 17, Joan Ellis, delineator.*)

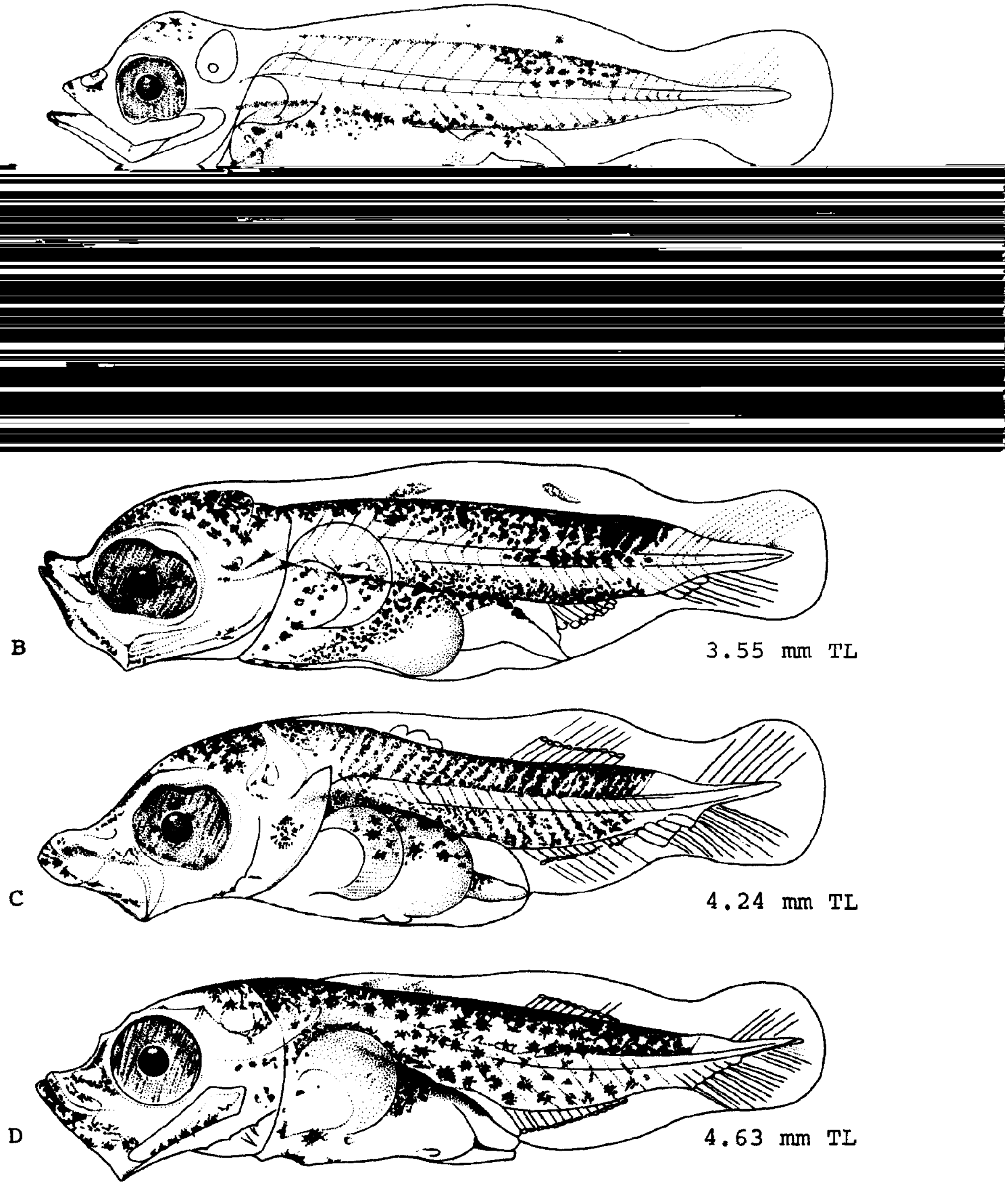
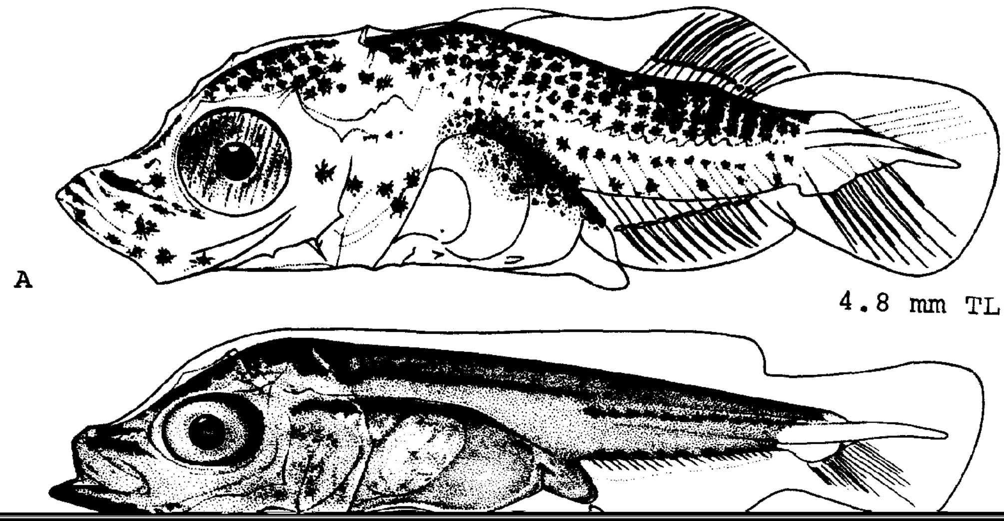
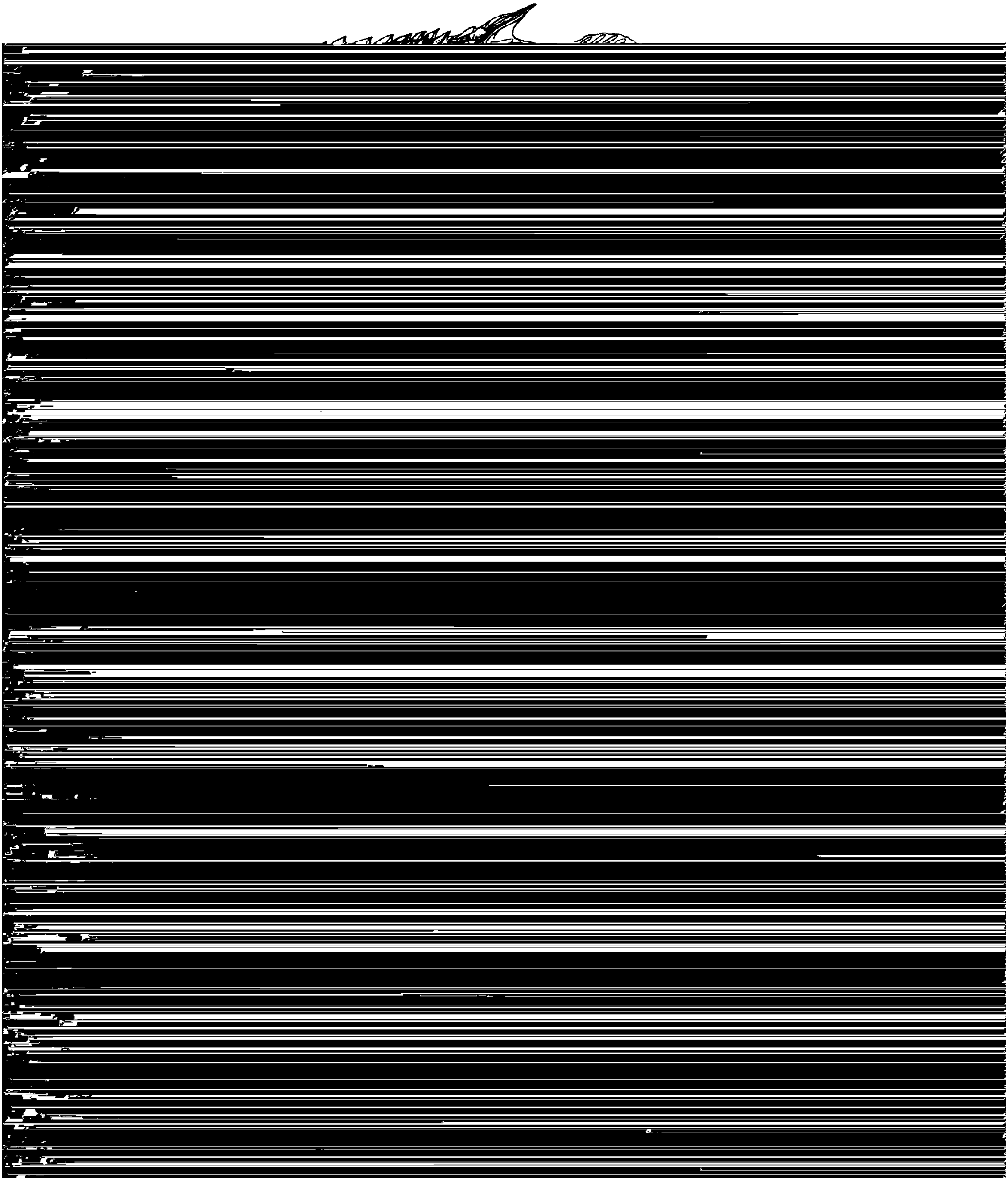


Fig. 225. *Macrorhamphosus scolopax*, Longspine snipefish. A. Larva, 2.8 mm TL, pigment in finfold greatly decreased, anus shifted conspicuously backward. B. Larva, 3.55 mm TL, body depth noticeably increased, incipient rays in caudal and anal. C. Larva, 4.24 mm TL, snout becoming elongate. D. Larva, 4.63 mm TL, head spinations developing. (*A-D, Sparta, A., 1936: figs. 6–9, Elizabeth Ray Peters, delineator.*)


A
4.8 mm TL



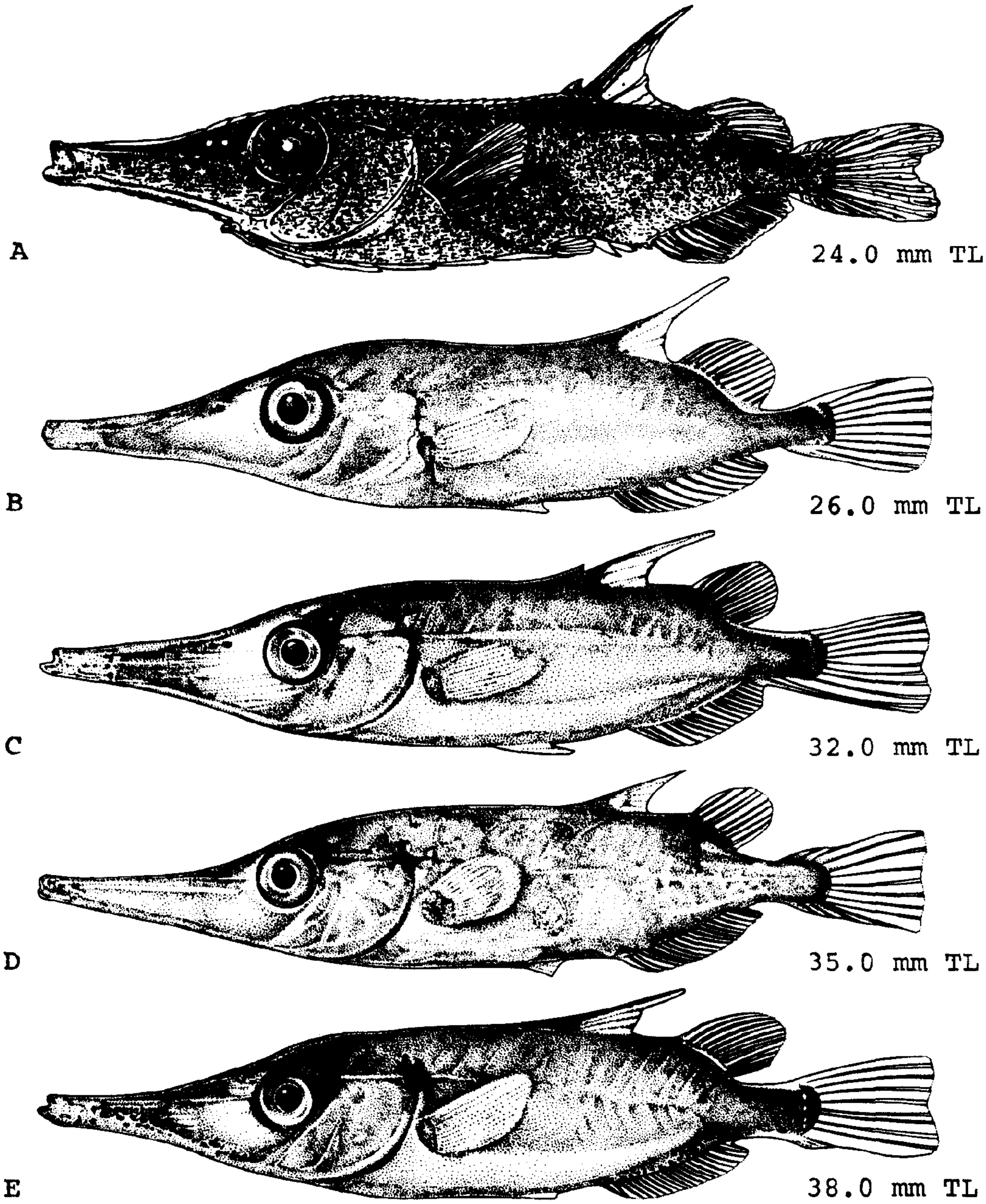


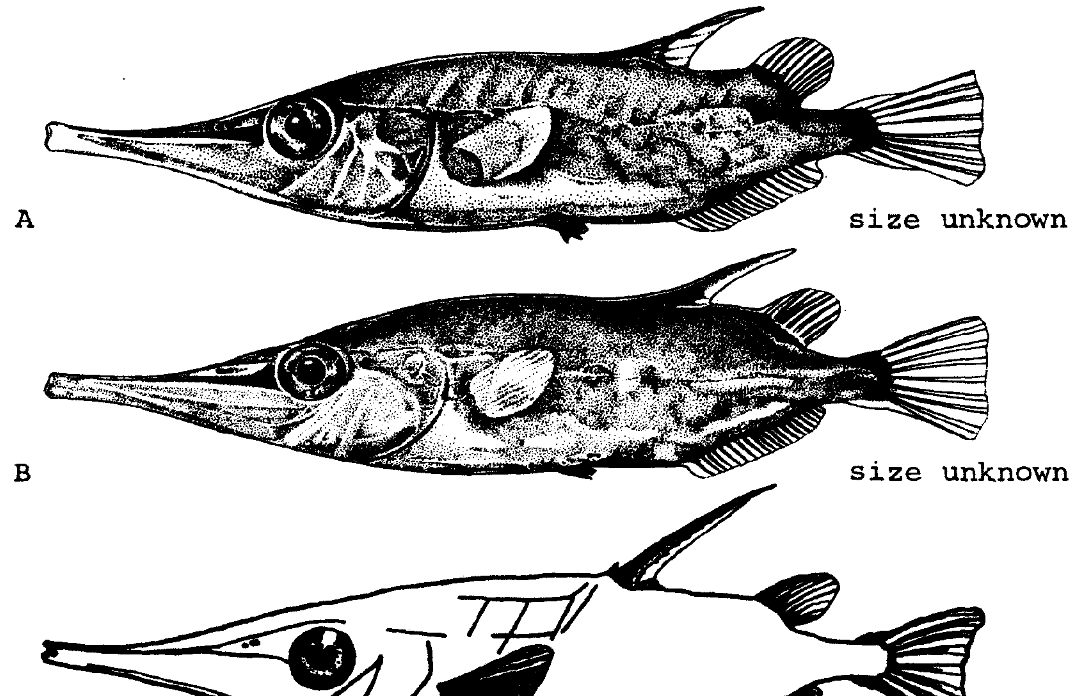
Fig. 230. *Macrorhamphosus scolopax*, Longspine snipefish. A. Prejuvenile, 24.0 mm TL. Prejuvenile, 26.0 mm TL. C. Prejuvenile, 32.0 mm TL. D. Juvenile, 35.0 mm TL. E. Juvenile, 38.0 mm TL. (*A, Uchida, K., 1958: pl. 45. B-E, D'Ancona, U., 1933: pl. 18, Elizabeth Ray Peters, delineator.*)

of eye. Caudal fin bilobed at 24.0–25.0 mm. Scales adult-like at 25.0 mm.[4,25]

Pigmentation: Blue above, silvery on sides and below throughout stage. At 30–35 mm black pigment along major spine of first dorsal and at bases of 2nd dorsal and caudal rays. Loss of prejuvenile pigment may take place in specimens as small as 35.0 mm,[25] while in other prejuveniles the blue pigment may be retained to at least 51 mm.[2]

JUVENILES

Minimum size, 35 mm.[25]


A
size unknown
B
size unknown

Hippocampus erectus
Hippocampus obtusus
Syngnathus floridae
Syngnathus fuscus
Syngnathus louisianae
Syngnathus pelagicus

pipefishes and seahorses
Syngnathidae

FAMILY SYNGNATHIDAE

Members of the family Syngnathidae occur in tropical and temperate waters throughout the world. There are two subfamilies: the Syngnathinae (pipefishes), which contains 34 genera and approximately 150 species, and the Hippocampinae (seahorses) with two genera and about 25 species. Seahorses are found exclusively in marine and estuarine waters, while some pipefishes occur in freshwater. Syngnathid fishes are primarily inshore, coastal species and are frequently associated with reefs or grass beds. At least one species, *Syngnathus pelagicus,* may occur far offshore among drifting sargasso weed. Certain poorly known species are thought to burrow in the substrate.

These relatively small fishes (adults 25 to about 460 mm) are immediately distinguishable by their elongate bodies which are encased in a series of bony rings. Other characteristics include a tubular snout; a small, toothless mouth; tufted gills; a lack of pelvic fins; a very small anal fin; and a primitive kidney. In the subfamily Syngnathinae the head and body are in the same plane, the caudal fin is not distinct, and the tail is non-prehensile. In the Hippocampinae the tail is prehensile, the head is at a right angle to the body axis, and there is no caudal fin. The prehensile-tailed *Amphelikturus* (currently assigned to Syngnathinae) has a slightly cocked head; and the caudal fin is noticeably reduced. It appears to be intermediate between the two subfamilies.

Spawning, which in some species may occur throughout the year, sometimes involves complex behavioral patterns. In *Syngnathus floridae,* for example, a distinct "liebenspiel" proceeds copulation. Both pipefishes and seahorses produce snapping sounds which may or may not be associated with courtship.

Eggs are carried by the male parent. In pipefishes they may be attached to the underside of either the abdomen or the tail; and may be fully exposed to water, or completely covered by the lateral folds of the brood pouch. Four modifications of the pipefish marsupium have been described. The lateral folds may be short and fail to cover the eggs, they may be long and cover the eggs completely by overlapping at the center, they may turn inward and divide the eggs in the pouch into two sections, or one flap may turn back on itself with the other flap overlapping it. In seahorses the marsupium is always under the tail, and is completely sealed for most of its length. During copulation the eggs are transferred directly from the oviduct into the marsupium.

Pipefish eggs are round, ellipsoidal, or irregular in shape. They may be various shades of yellow or orange (depending on the species), and sometimes have numerous brightly colored (red or orange) oil globules. Seahorse eggs are either oval or pear-shaped and are typically red or orange. In the eggs of most species there are, numerous oil globules, but one author has reported that oil globules are absent in *Hippocampus abdominalis.*

Early workers suggested that, in spite of the large amount of yolk present, developing eggs of *Syngnathus dumerili* and *S. typhle* receive additional nourishment directly from the male parent through the brood pouch. More recently Linton and Soloff (1964), working with *Hippocampus erectus,* concluded that the brood pouch epithelium actively transports sodium; that the pouch is, consequently, a highly effective osmoregulatory organ; that calcium is absorbed by the developing embryos from the pouch fluid; that the source of this calcium may be the bony rings of the male parent; and that "the impermeable nature of the pouch makes it almost certain that the exchanges of gases and nitrogenous waste products occur across the pouch epithelium."

The eggs hatch in the marsupium. In at least one seahorse (*Hippocampus* *zosterae*) parturition is accompanied by extreme contortions of the male's body and the young, which are usually born head first, leave the pouch with explosive violence. Young of both subfamilies are well-developed and swim freely immediately after birth. Some young pipefishes (*Entelurus* and *Nerophis*) are born with a larval finfold and may live pelagically for a brief period, while others, such as S. *typhle* and S. *acus*, are born in a very advanced state and may descend immediately to the bottom.

Young stages of the regional syngnathid fishes have not been adequately described and insufficient data exists on which to base a key. A review of meristic and pigmentary characteristics which may be useful in attempting to identify these stages is presented in table 17.

TABLE. 17. Meristic and pigmentary characteristics of early stages of syngnathid fishes of the Mid-Atlantic Bight.

	Trunk rings	Caudal rings	Pigmentation
H. erectus	10–11	32–37	At hatching head unpigmented, body with alternating light and dark bands, pigment on gut and along dorsal base.
H. obtusus	10	35	No information.
S. floridae	16–19 (20)	30–37 (39)	Earliest stages undescribed. At 14 mm a mid-lateral pigment band, chromatophores on belly, top and sides of head, snout, and along dorsal and ventral line.
S. fuscus	17–21	33–42	Slight pigment in eye at hatching, apparently no pigment on body. In later stages a distinct series of dark vertical bands on body.
S. louisianae	19–21 (23)	34–39	No information.
S. pelagicus	16–18	30–34	(Based on pre-hatched embryos.) Eyes darkly pigmented, a heavy mid-lateral pigment band, pigment on snout and to indeterminate degree along dorsum.

The inclusion of *Hippocampus obtusus* is provisional. Mrs. Myvanwy Dick, of the Museum of Comparative Zoology, is reviewing this species and feels that it may be the juvenile of some other form. The type specimen of *H. obtusus* is presumably an immature male.

Hippocampus erectus Perry, Lined seahorse

ADULTS

D. 17–22;[16] A. 3[28]–4;[8] P. 15–19;[24] V. 4;[5] trunk segments 10[1,11]–12;[32] caudal segments 32[1]–37;[41] vertebrae 13+36–38.[43]

Proportions as times in length: Head 3.9–4.7; depth 5.0–5.6 in females, 4.25–5.1 in males.[47] Snout 1.9[15]–2.7 times in head. Eye 2.4–2.9 times in snout,[47] 5.1–6.6 times in head.[15] Head in trunk, measured over back from gill opening to end of dorsal base, 1.6–2.3.[32]

Body deep, compressed, robust, 7-angled; tail tapering, quadrangular, prehensile; head deep, compressed, at right angle to body; profile deeply concave posteriorly; mouth vertical.[8,15,16,32] Dorsal fin over 2.5–4.0 body segments, 1–2 caudal segments.[16,32]

Pigmentation: Color and pattern highly variable. Ground color blackish, silver-gray,[22] ash gray,[33] light brown, dusky, yellow,[31] or brick red.[22,36] Nearly uniform[8] to variously mottled and blotched,[33,34] the blotches with contrasting paler or darker edges. Some specimens with hourglass blotch extending down each side of back;[38] others with striped pattern composed of a single narrow dark brown or black transverse line on trunk.[11] Sometimes sprinkled with white,[36] silver,[34] or light blue dots,[38] particularly on head and posterior part of body. Edge of dorsal fin orange in males, yellow in females.[11,36] Capable of color changes, as from uniform black by day to lightly barred at night.[17]

Maximum length: Ca. 203 mm.[16]

DISTRIBUTION AND ECOLOGY

Range: Nova Scotia and Georges Bank to Argentina;[5,39] Bermuda;[11] and at least part of the West Indies.[6,11,39]

Area distribution: North in Chesapeake Bay at least to vicinity of Calvert County, Maryland;[28,42] Virginia;[32]

Chincoteague and Sinpuxent Bays;[20] Delaware;[9,29] New Jersey.[8,9]

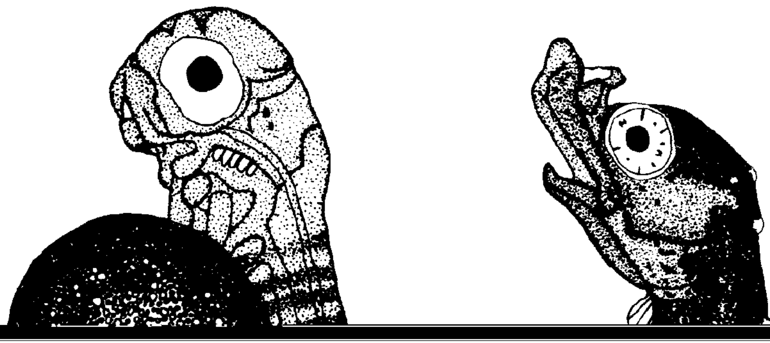
Habitat and movements: Adults—at surface[19] and bottom[35] of both shallow water[6] and deeper areas of channels[14,40] in bays,[27] along beaches,[35] in or near salt marshes,[23,35] and over oyster beds[9] and weed covered banks.[16] May enter rivers,[3] and sometimes at surface in water up to 38 m deep.[18,19] Usually associated with or clinging to aquatic vegetation such as *Thalassia, Agardhiella*[20] eel grass,[23,35] and sargasso weed.[19,35] Salinity range, 10.0[45]–36.6 ppt.[48] Temperature range, 5.0–29.9 C.[45] Maximum distance from shore, 22 km.[30] Maximum depth, 46 m.[32] Apparently make annual inshore-offshore movements: Inshore from July to September at Woods

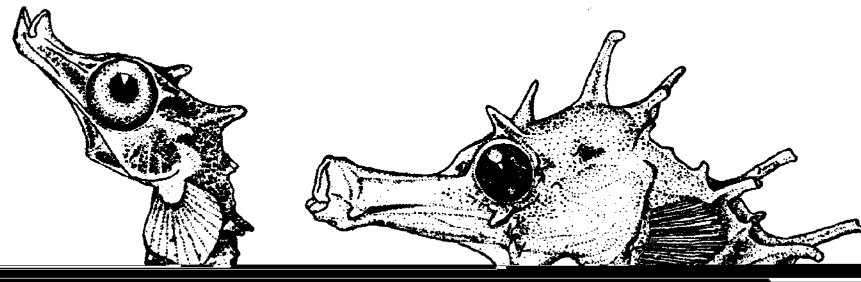
Juveniles—"Recently born" recorded from rivers entering the Potomac;[50] specimens 6.0–33.0 mm long in masses of floating sea weed in lower Chesapeake Bay.[25] Specimens up to 95.0 mm long pelagic, in comparatively deep offshore waters;[10,21,27] recorded from near the 183 m contour.[44] A 30 mm specimen recorded from 12.1 ppt salinity.[46]

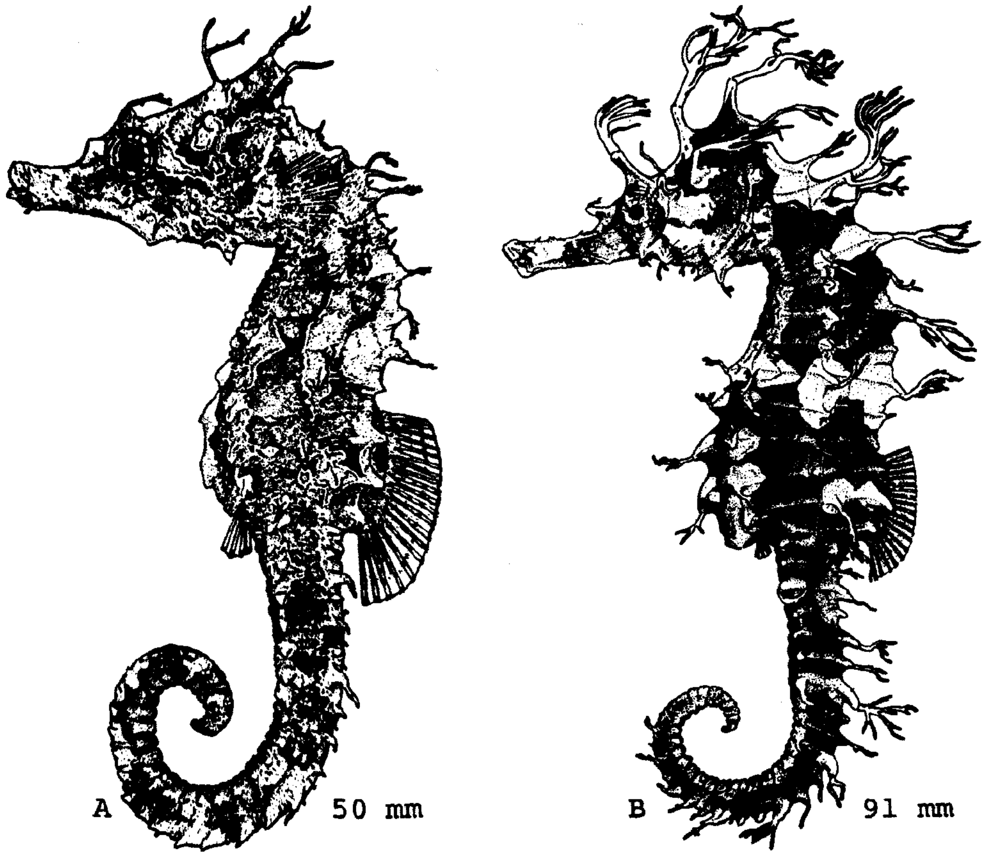
SPAWNING

Location: Presumably inshore (JDH); incubating males recorded in Great South Bay, Long Island, New York.[3] Unknown except by inference.

Season: Young 6.0–33.0 mm recorded from Chesapeake







[redacted]

Hippocampus obtusus Ginsburg, Offshore seahorse

ADULTS (OR ADVANCED JUVENILE)

D. 17;[1] P. 16[4]–17; trunk rings 11;[1] caudal rings 35.[4]

Proportions as percent length: Depth 18.8, head 24.5, snout 10.7, eye 4.4, postorbital 10.8, trunk 35.2, tail 60.9.[5]

Trunk conspicuously slender, snout rather long. First caudal segment hexangular, last caudal trunk segment octangular. Every third or fourth tubercle on trunk and anterior part of tail very stout, bluntly obtuse.[4]

Pigmentation: No information.

Maximum size: 70 mm.[4]

DISTRIBUTION AND ECOLOGY

Range: Atlantic coast from New Jersey[3] to Florida;[1] in Gulf of Mexico recorded from Louisiana;[2] also St. Lucia in the Caribbean, and Bermuda.[1]

Area distribution: Various stations within the 183 m contour between central New Jersey and mouth of Chesapeake Bay.[3]

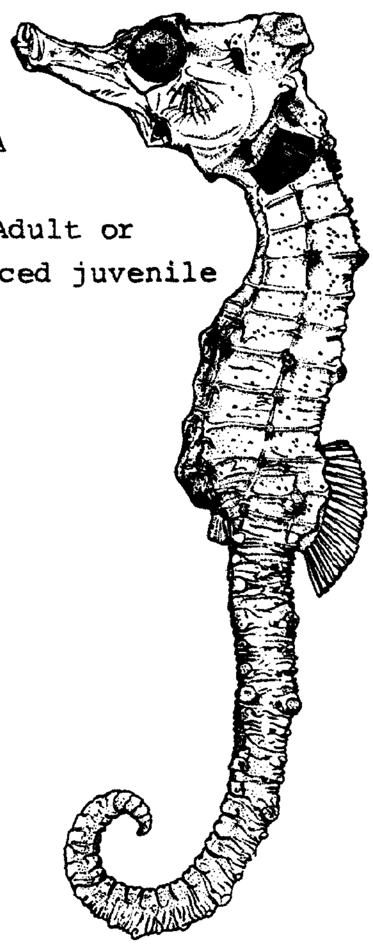
Recorded temperature range 22.2[2]–31.0 C.[1]

SPAWNING

No information.

A

Adult or advanced juvenile



70.0 mm TL

Fig. 238. *Hippocampus obtusus*, Offshore seahorse. A. Adult or advanced juvenile, 70.0 mm, a male with brood pouch just developing. (*A, Ginsburg, I., 1937: fig. 67.*)

EGGS

No information.

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

AGE AND SIZE AT MATURITY

A 70 mm male with brood pouch just developing.[4]

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Syngnathus floridae (Jordan and Gilbert), Dusky pipefish

ADULTS

D. 27 [4]–34; [24] A. 3; C. 10; [2,4] P. 13–15; [9] trunk rings 16–19 [2,4] or 20; [22] caudal rings 30–37 [4] or 39; [11] vertebrae 18 + 33 – 34.[29]

Proportions as times in SL: Head 5.2–6.8, usually 5.4–5.9. Proportions as times in TL: head 4.75 [20]–7.8, tail 1.7–1.8.[11] Proportions as times in head: dorsal 1.35–1.85, usually 1.45–1.70; snout 1.6–1.88.[2]

Caudal portion of body quadrangular.[31] Females slightly V-bellied,[2,4] and apparently increasing significantly in depth from 165–200 mm.[24] Dorsal fin on 1/2–2 [2] or 3 [11] trunk rings and 4.5–7 [11,22,36] caudal rings. Brood pouch on 17–20 rings [4] (counts of 13–15 [24] are probably based on immature or nonegg-bearing males, JDH). Contacting edges of brood pouch covered with small papillae.[4]

Pigmentation: Usually light to dark green,[1,14] the shade varying with surroundings; [23] also reported as yellow, buff,[11] or light gray; [24] center of each segment slightly lighter than ground color; [11] lateral stripe lacking; [16,25] sides more or less spotted or streaked with gray, white, or blue [11,14,24,25] and with 5–10 narrow light bands before dorsal, 5–7 behind; underside of belly and tail sprinkled with light on dark background in males; area below lateral keel light lemon yellow in large females; [24] tail

and pale oblong spots; snout mottled, especially on sides; lower part of opercle nearly plain; dorsal fin translucent, yellow at base; anal fin plain; caudal fin yellow, dusky at base.[6,14,16,25]

Maximum reported length: Ca. 229 mm.[14]

DISTRIBUTION AND ECOLOGY

Range: Chesapeake Bay to Panama,[2,27] also the West Indies,[21] Bermuda [2,9,19] and vicinity of the Azores; [30] absent between Seabrook Beach, South Carolina, and Miami, Florida.[2]

Area distribution: North in Chesapeake Bay to Plum Point, Calvert County, Maryland; [2,5] Virginia; [4,8,20] Chincoteague Bay.[13]

Habitat and movements: Adults—over sand [8] or mud [1,10] bottoms of shores,[3,8,25] flats,[10] bays,[7] harbors,[1,18] tide basins,[12] and mouths of creeks; [26] usually associated with aquatic vegetation such as *Zostera*,[1,14] *Ulva*, *Agardhiella*,[27] and turtle grass; [15,24] also sometimes associated with sargassum.[30] Salinity range, 12.3 [7]–38.8 ppt,[34] but most abundant at 17.0–22.0 ppt.[27] Maximum recorded temperature, 31.0 C.[34] In vicinity of Chesapeake Bay move out into deeper water during winter months,[4] return inshore reaching peak inshore abundance in late July and early August, remain inshore until October.[27] In more southern latitudes, movements apparently reversed, most abundant inshore in Florida Bay from October through February.[17]

Larvae—carried in brood pouch of male until about 11.5 mm long.[28]

Juveniles—"small specimens" in harbors and bays;[33] specimens 41.6–79.0 mm long inshore in June at Tampa, Florida.[17] Salinity range, 19.0–27.0 ppt. Temperature range 25.1–29.8 C.[36]

SPAWNING

Location: Not definitely stated, but presumably inshore (JDH).

Season: In Tortugas, males with eggs in June and July; June to August at Beaufort, North Carolina;[14] males with eggs from May to October in Chesapeake Bay,[20] although spawning possibly as early as April in lower Chesapeake Bay, peak activity in late July and August;[27] during all months but January in Florida.[2,10,17,24,30]

Time: Occurs at night or early morning.[1,14]

Fecundity: Mature ova 140-ca. 1100, average 519. Brood pouch capacity: 130–447, average 263.9.[10]

EGGS

Location: Deposited in brood pouch of male. Initially loosely arranged, later in 2–4 rows and 1–2 layers in each side of pouch[2,4,15] and firmly attached to pouch within 36–48 hours (eggs in 3 different stages of development may be found in brood pouch).

Unfertilized egg: Diameter ca. 1.0 mm, yolk straw-colored and with many oil globules in periphery.[1]

Fertilized egg: Diameter, from average of 0.9 mm[2] to extreme of 1.2 mm.[4]

EGG DEVELOPMENT

Development at unspecified temperature:[1]

Blastodisc stage—blastodisc button-shaped, highly arched, clearly marked off by circumferential furrow; disc rests on orange-red layer of oil globules covering about 1/4 of yolk; during this stage yolk clears; disc may form without fertilization.

2-cell stage (probable age 4–6 hours)—just prior to cleavage, blastodisc somewhat elongated; blastomeres may be of unequal size; cleavage furrow not reaching yolk.

4-cell stage—second cleavage crosses first at right angles; segmentation cavity evident.

8-cell stage—blastoderm considerably elongated; blastomeres may be irregular in size and shape and develop in layers rather than flat.

32-cell stage—cells piled up and irregular (a 16-cell stage was described in which 90% of the eggs examined were atypical of normal teleostean development).

Advanced morula—surface cells flattened, periblast free from yolk.

Just prior to invagination—blastoderm spreading over yolk; cells crowded into high arched band; subgerminal cavity large.

At ca. 4 days—tail free.[1]

Incubation period: Ca. 10 days.[14]

YOLK-SAC LARVAE

Specimen described, 11.5 mm TL.

At 11.5 mm TL, yolk visible only in cross-section[1] (although other specimens of this size apparently lack yolk).[28]

LARVAE

Size range described, 14.25–18.5 mm TL.

At 14.25 mm TL, body segments 19+31; dorsal, caudal, and pectoral fins fully developed (AJL). Remnant of continuous finfold evident, especially ventrally, in specimens less than 18.5 mm long.[1]

Pigmentation: At 14.25 mm TL, a clear band mid-laterally on body; chromatophores developed over belly, on top and sides of head, on snout, and dorsally and ventrally along body (AJL).

JUVENILES

Minimum size unknown.

Body more slender in "young" than in adults.[20] Incipient male brood pouch at 46 mm.[9]

AGE AND SIZE AT MATURITY

Minimum age at maturity unknown. Minimum size at maturity, for males 104 mm,[9] females 75 mm.[4]

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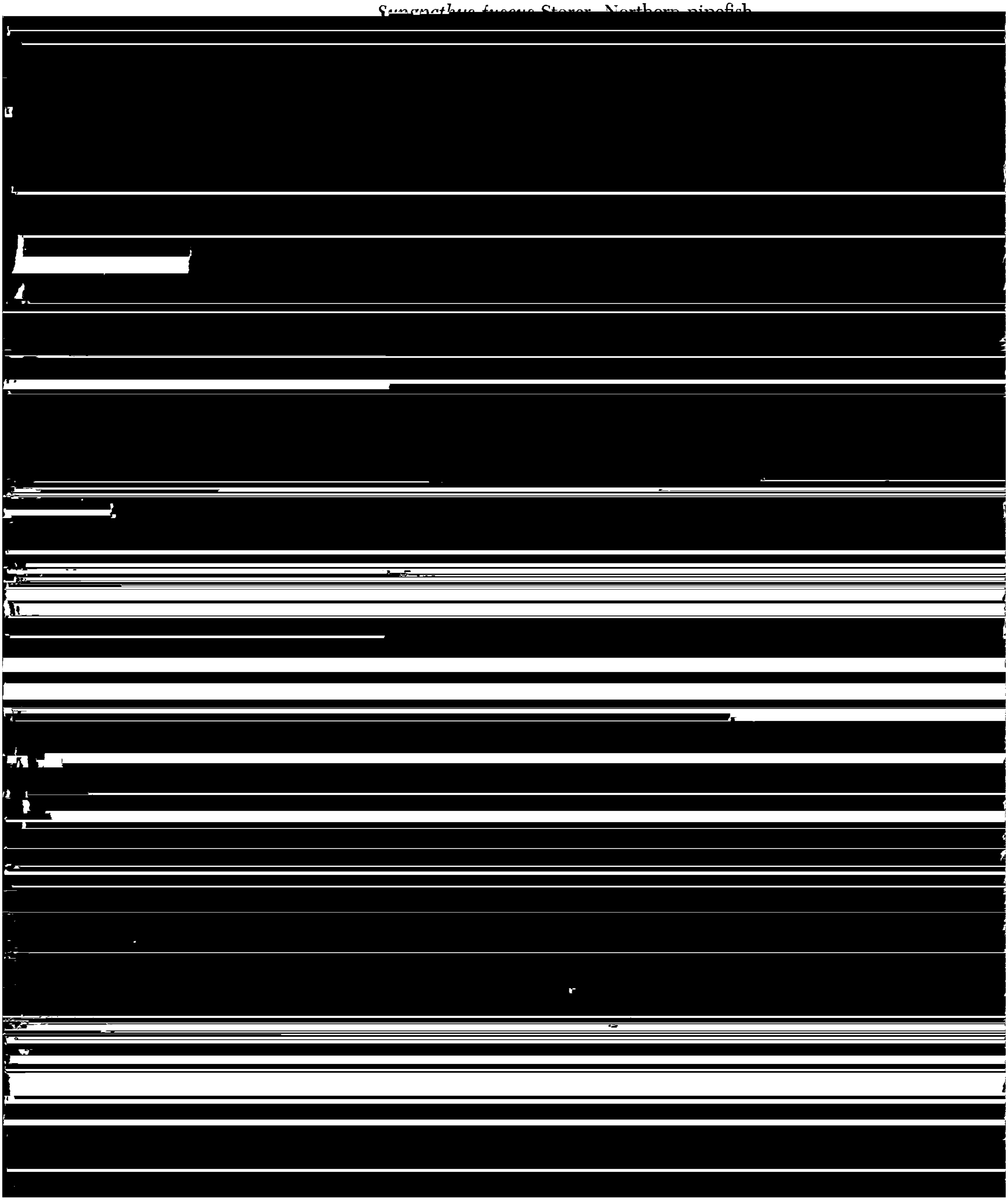
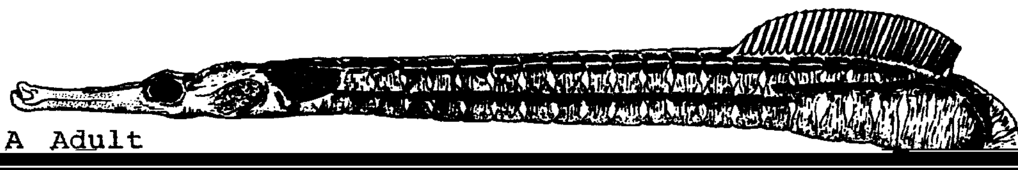
Syngnathus fuscus Storer, Northern pipefish





A Adult

orange-yellow, and with deeper-colored oil globules.[18,19]

EGG DEVELOPMENT

Incubation period: Ca. 10 days.[31]

YOLK-SAC LARVAE

Minimum hatching length, ca. 3.0 mm.[18] *Maximum* length described 6.0–7.0 mm.[2]

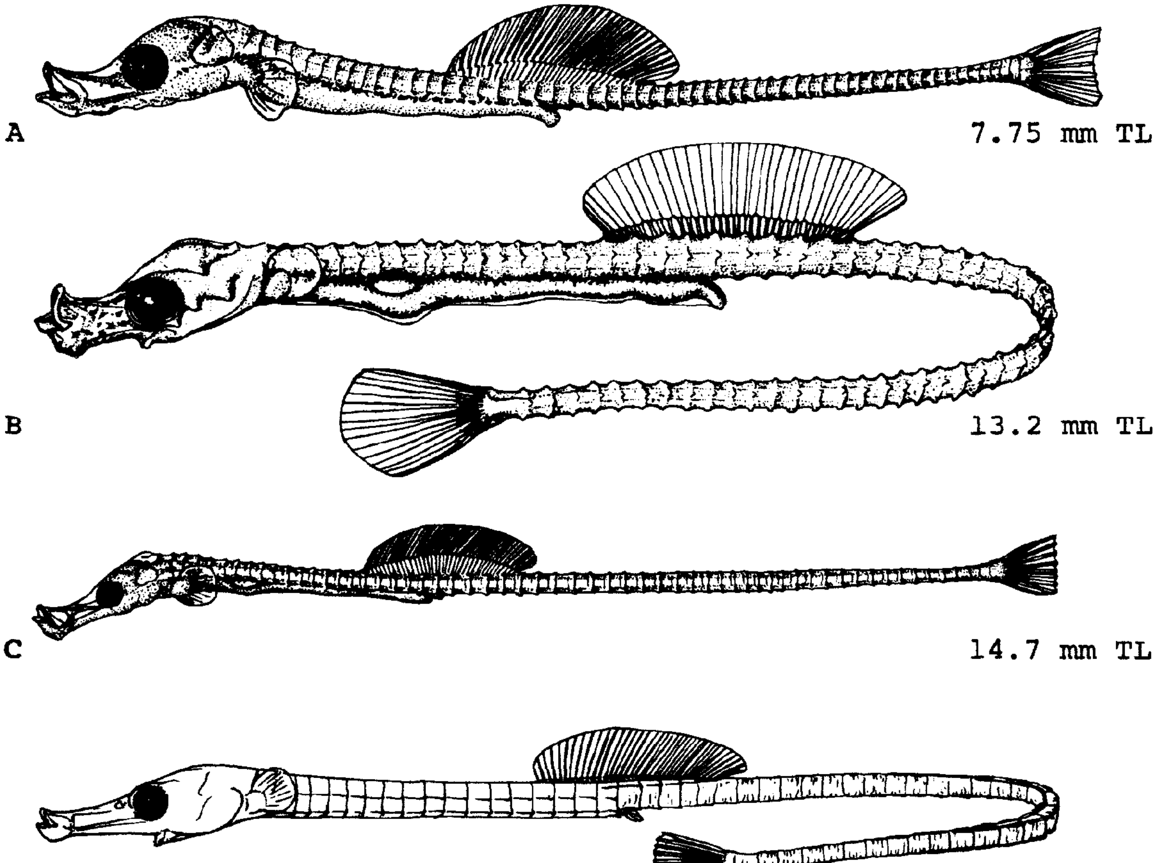
Head deflected downward at 3.0 mm, straight at 3.5 mm.[18] Snout beginning to elongate at 6.0–7.0 mm.[2] Yolk mass nearly spherical at 3.0–3.5 mm,[18] oval at 4.0–7.0 mm.[2] Mouth apparently not formed at 3.0 mm, well-developed and vertically oriented at 3.5 mm. Choroid fissure retained to at least 3.5 mm.[18] Auditory capsules, otoliths first visible at 3.0–4.0 mm.[2] Branchial arches formed at 3.5 mm,[18] branchial cavity completely enclosed in cartilage throughout stage.[34] Nares developed, visible from above, at 6.0–7.0 mm.[2] Finfold poorly developed,[19] or absent.[18] Origin of incipient dorsal fin over anus at ca. 3.0 mm; anus under center of developing dorsal fin at 3.5 mm. Anal fin may be absent at hatching,[18] although evident, at least in some specimens, at 3.0–4.0 mm.[2] End of tail rounded and lacking fin at 3.0 mm; incipient caudal rays at 3.5 mm. Pectoral buds evident at 3.0 mm, pectoral fins partly rotated on bases at 3.5 mm.[18] Urostyle oblique at 3.0–4.0 mm. Gut straight, intestinal valve developing at ca. 7.0 mm.[2]

Pigmentation: Undescribed, but illustrations suggest that eye is partially pigmented at hatching (JDH).

LARVAE

Size range described, 7.75 (AJL)–20.0 mm.[6]

At 12.0 mm, 5 branchial arches formed, olfactory nerves



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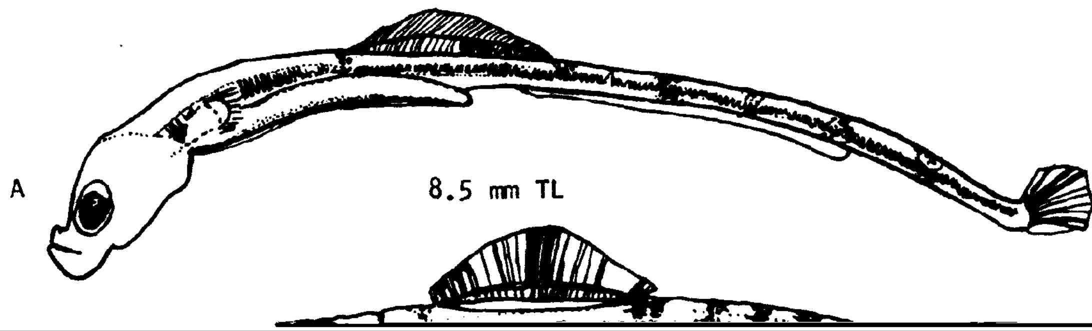
A
8.5 mm TL

Syngnathus louisianae Günther, Chain pipefish

ADULTS

D. 30–40; A. 2–3; [22,31,33] C. 10; P. 13–16; trunk rings 19–21 [1] (but also reported to 23 [4]), usually 20; [24,25] tail rings 34–39; [1] vertebrae 19–20 + 32.[27]

Proportions expressed as times in TL: Depth 27–32,[18] head 6.5 [31]–8.5,[18] tail 1.78.[2] Snout in head 1.58–1.88.[33]

Trunk broader below,[2] flat [25] or slightly concave and with median ridge; [2,19] occiput, nuchal plates, and opercle somewhat keeled.[11] Dorsal fin over 1.5 [33]–4 [4] + 4–6 rings,[1] average dorsal coverage, 7.5 rings.[31] Brood pouch on 17–19 [18] or possibly 20 [25] rings.

Pigmentation: Usually light brown with or without darker diamond-shaped reticulations; lower parts of trunk and abdomen lighter; with or without a well-marked lateral brown band extending through eye to end of snout; dorsal sometimes with 7 vertically diagonally dark brown stripes; caudal usually blackish brown; other fins plain.[1,4,9,17]

Maximum length: 326 mm.[24]

DISTRIBUTION AND ECOLOGY

Range: In continental North America from Chesapeake Bay, Maryland, to Aransas Bay, Texas; [1,22] also reported from Campeche, Mexico,[33] Bermuda,[4] Jamaica,[32] and throughout Gulf of Mexico.[20]

[redacted]

0.00 [21]–45.0 ppt.[8] Maximum recorded temperature 34.9 C.[29]

Larvae—held within male brood pouch (JDH).

Juveniles—apparently more inshore than adults; [12] taken from "boiling surf" in Texas.[1] Salinity range 13.1–36.5 ppt. Temperature range 12.4–30.8 C.[33]

SPAWNING

Location: Unknown; males with advanced eggs on grassy shoals at Beaufort, North Carolina,[9] also in offshore waters of Gulf of Mexico.[6,7]

Season: May and June in Texas,[8] with brooding males reported in Texas in July; [7] brooding males reported in early June at Beaufort, North Carolina,[9] mid-February at Campeche, Mexico,[6] July in Gulf of Mexico,[7] and September in Florida.[13]

EGGS

Deposited in 1 or 2 layers and 4–6 rows on each side of male brood pouch; diameter, 0.7–0.8 mm.[1]

YOLK-SAC LARVAE

No information.

nounced spines or ridges. Brood pouch beginning to form at ca. 180 mm.[1]

Pigmentation: In "juveniles" often ca. 5 trunk and 8–9 caudal rings of dark brown,[1] "young" also described as with reticulated chain-like pattern.[33]

AGE AND SIZE AT MATURITY

Smallest confirmed mature male 200 mm,[1] but possibly as small as ca. 185 mm.[13]

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Syngnathus pelagicus Linnaeus, Sargassum pipefish

ADULTS

D. 28–31;[6] A. typically 3 (CED); C. 10; P. 13–14;[4] trunk rings 16–18;[6] tail rings 30–34; dorsal fin on 0.75–2.25 trunk rings, 4.25–7.00 tail rings;[8] brood pouch under 12–15 tail rings.[6]

Head 6.6 times in TL, about twice in trunk; eye ca. 6 times in HL;[4] pectoral fin 5.2–6.3 times in HL.[6]

Body rather slender, trunk heptagonal, tail tetragonal,[4] females distinctly V-bellied.[6] Body rings transversely striated, their edges pronounced but smooth.[4]

Pigmentation: Ground color brown,[4] lower half of each trunk segment usually with a narrow black-margined vertical white line or spot; upper half of trunk and all of tail not distinctly marked, but with some light areas on each segment;[6] also described as having a faint silvery transverse bar on trunk rings and a light transverse bar on every third caudal ring;[4] dorsal fin with a dark stripe down middle and several basal clumps of dark pigment.[6]

Maximum length: 165 mm SL (CED).

DISTRIBUTION AND ECOLOGY

Range: Atlantic, Indian, and western Pacific oceans, and the Mediterranean Sea; in the western Atlantic, Gulf of Maine to Argentina,[1] (but southern limit questioned, CED) including Bermuda,[1] the Sargasso Sea,[3] the West Indies,[4] and the Gulf of Mexico. Also recorded from the coast of West Africa.[5]

Area distribution: Inshore along coast of northern New Jersey.[7]

Habitat and movements: Adults—associated with sargasso weed.[2,9]

Larvae—recorded over depths of 73–3220 m;[10] a specimen 9.5 mm long collected ca. 1370 km off the coast of Africa.[5] Recorded salinity range 23.3[8]–35.9.[5]

Juveniles—no information.

SPAWNING

No information.

EGGS

Early eggs round, advanced eggs elongate, tubular. Advanced embryos with a heavy mid-lateral pigment band, pigment on snout and to indeterminate degree along dorsum; eyes darkly pigmented (JDH).

EGG DEVELOPMENT

No information.

YOLK-SAC LARVAE

No information.

LARVAE

No information.

JUVENILES

No information.

AGE AND SIZE AT MATURITY

Males with eggs in brood pouch as small as 71 mm SL (CEL).

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A
100 mm TL

Fig. 245. *Syngnathus pelagicus,* Sargassum pipefish. A. Adult, 100 mm TL. (*A, Böhlke, J. E., and C. C. G. Chaplin, 1968: 190.*)

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